

SITE: Carrier Air
BREAK: 6.3
OTHER: V4

**CARRIER COLLIERVILLE SITE
DRAFT PRELIMINARY DESIGN REPORT
SOIL VAPOR EXTRACTION
MAIN PLANT AREA**

**Prepared for:
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Collierville, Tennessee 38017**

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JANUARY 7, 1993



10663655

Table of Contents

1.0	RESULTS OF DATA ACQUISITION ACTIVITIES	1
1.1	INTRODUCTION	1
1.2	SITE HISTORY AND DESCRIPTION	1
1.2.1	Site Location and Land Use	1
1.2.2	Facility Operations and History	2
1.2.3	Previous Removal/Remedial Actions	4
1.2.4	Geology and Physiography	5
1.2.5	Hydrogeology	5
1.3	SUMMARY OF NATURE AND EXTENT OF SOIL CONTAMINATION	6
1.3.1	Contaminants of Concern	6
1.3.2	Contaminant Distribution, Fate and Transport	8
1.4	SOILS REMEDIATION CRITERIA FOR GROUNDWATER PROTECTION	8
1.4.1	MULTIMED Application	9
1.4.2	Soil Clean-Up Level	9
2.0	DESIGN CRITERIA REPORT	11
2.1	SOIL VOLUMES REQUIRING TREATMENT	11
2.2	SVE TREATMENT OF CONTAMINATED SOILS	11
2.2.1	SVE at the MPA	12
2.2.2	Off Gas Treatment of Vapor-Phase Contaminants	13
2.3	SVE INPUT/OUTPUT RATES	14
2.4	INFLUENT AND EFFLUENT QUALITIES	14
2.5	EVALUATIONS CONDUCTED TO SELECT THE DESIGN APPROACH	16
2.6	MATERIALS AND EQUIPMENT	17
2.6.1	SVE Extraction Wells and Monitoring Points	17
2.6.2	Vacuum Pump	18
2.6.3	Vapor/Liquid Separator	18
2.6.4	Surface Seals	18
2.6.5	Off-gas Emission Control	19
2.7	PERFORMANCE STANDARDS	19
2.8	DECISION RULES	19
2.9	LONG TERM MONITORING REQUIREMENTS	19
2.10	RESULTS OF THE SVE TREATABILITY TEST	20
3.0	PRELIMINARY PLANS AND SPECIFICATIONS	21
4.0	PLAN FOR SATISFYING PERMITTING REQUIREMENTS	22
5.0	DRAFT CONSTRUCTION SCHEDULE	23

List of Figures

Figure 1-1	Site Plan	3
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List of Appendices

Appendix A	MPA Treatability Study Report-Soil Vapor Extraction
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1.0 RESULTS OF DATA ACQUISITION ACTIVITIES

1.1 INTRODUCTION

This report has been developed per the Statement of Work (SOW) for Remedial Design and Remedial Action (RD/RA) for the Carrier Collierville site. This report presents results of SOW Task II remedial design activities. The report has been prepared in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), and the Superfund Amendments and Reauthorization Act of 1986 (SARA). It is based upon the findings of the Remedial Investigation (RI) and Feasibility Study (FS), Main Plant Area (MPA) Soil Vapor Extraction (SVE) Parameter Evaluation Tests (PET), and decisions regarding remedial actions that were presented by the United States Environmental Protection Agency (USEPA) in the *Carrier Air Conditioning Superfund Site Record of Decision* (ROD), September 3, 1992.

1.2 SITE HISTORY AND DESCRIPTION

The following section summarizes findings of the Remedial Investigation (RI). For more details concerning the methods and results of the RI, refer to the RI Report.

1.2.1 Site Location and Land Use

The Collierville site is located on the western side of Collierville in Shelby County, Tennessee. The county is located in the southwest portion of the state, bounded to the north by Tipton County, to the east by Fayette County, to the south by DeSoto County, Mississippi, and to the west by the Mississippi River. The site is located near the intersection of Poplar Avenue (U.S. Highway 72) and Byhalia Road. The address is 97 South Byhalia Road, Collierville, TN 38017. Collierville is located approximately 21 miles east of downtown Memphis, Latitude 35°02'33", Longitude 89°41'00". The site is located on the Collierville Quadrangle, USGS Topographic Map. Figure 1-1 shows the site and characteristics.

Prior to development in 1969 by the Carrier Corporation, the property located on Byhalia Road, was essentially farmland and prior to that, undeveloped. This land use description would include

all areas immediately surrounding the facility. Current land use in the immediate area is industrial/commercial and undeveloped.

1.2.2 Facility Operations and History

The site consists of approximately 135 acres owned principally by Carrier Corporation (Carrier) which operates a manufacturing facility on the property. Carrier, an air conditioning equipment manufacturer, developed the property in 1969-1970 and manufacturing began in 1971. Carrier's use consists primarily of four buildings: the main plant area (MPA) which is an assembly plant for air conditioning units, buildings A and F which contain manufacturing, storage and supporting operations, and an office building.

In 1967 the town of Collierville installed a well field for potable water on the northwest corner of the site. The operation consists of two wells, described as the West Well and the East Well, a treatment (aeration and chlorination) plant, and a storage tank. This area is identified as Well Field #2 and provides up to 1.4 million gallons per day of potable water to the town of Collierville. Although pumping rates vary depending upon demand, both wells are operational and currently in service.

About 1972, Carrier installed a wastewater surface impoundment on the northwest corner of the property. Data from the state's site investigation report indicate that the surface impoundment was approximately 50' by 48' and contained less than one foot of sludge at the time it was removed in 1980. The area was used for the storage of clarifier pit sludge which was essentially an alkaline zinc phosphate washer sludge according to plant personnel. Topography of the area was changed when the impoundment and a layer of subsoil beneath it were removed in 1980.

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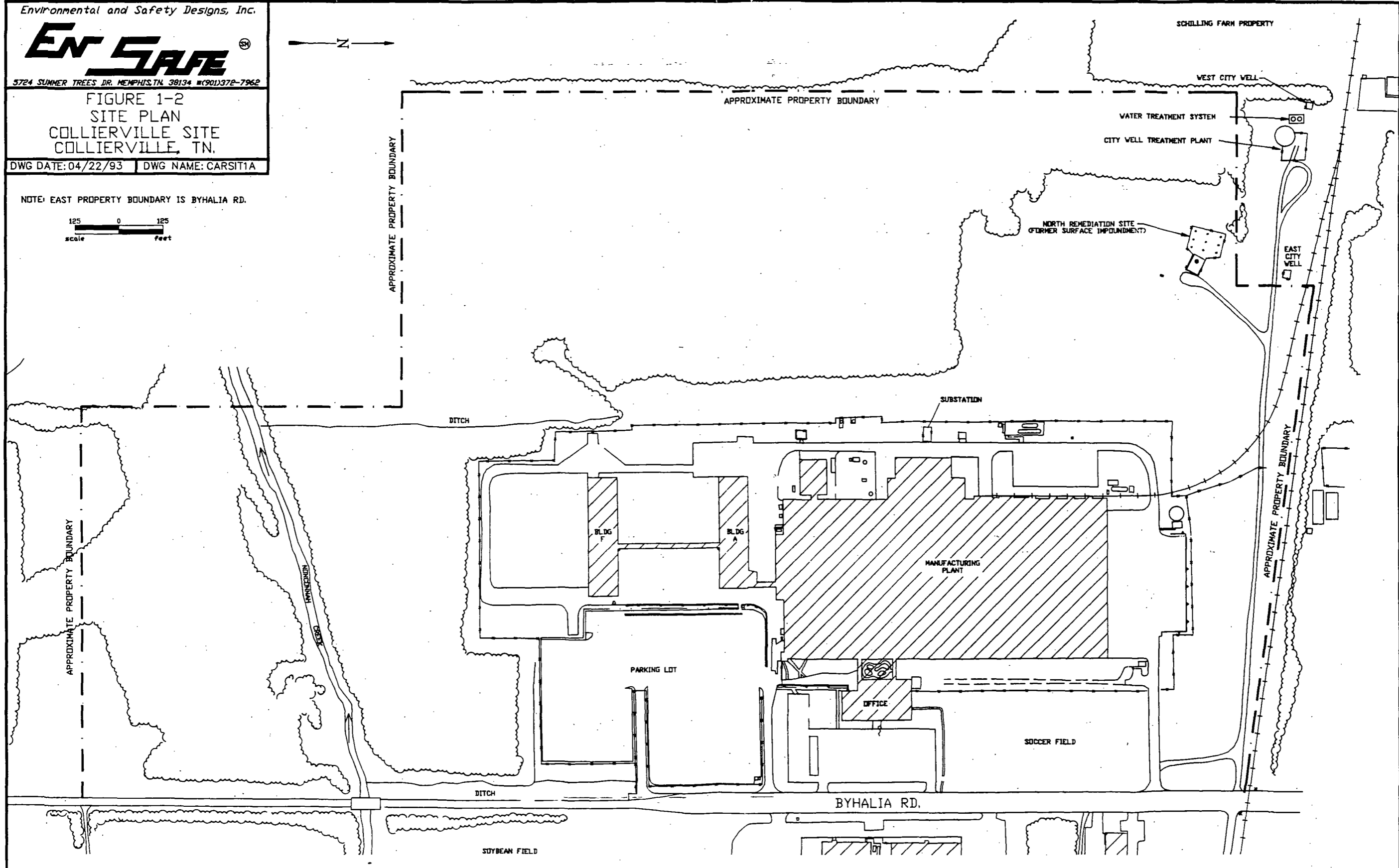
5724 SUMMER TREES DR. MEMPHIS, TN 38134 MC901378-7962

FIGURE 1-2
SITE PLAN
COLLIERVILLE SITE
COLLIERVILLE, TN.

DWG DATE: 04/22/93 DWG NAME: CARST1A

NOTE: EAST PROPERTY BOUNDARY IS BYHALIA RD.

125 0 125
scale feet



1979 TRICHLOROETHENE (TCE) SPILL

In 1979, the Carrier plant experienced a spill of trichloroethylene from a heated degreasing unit located on the south side of the plant. The spill occurred as a result of the failure of a filter cover on the unit. At the time of the spill, it was estimated that several thousand gallons of trichloroethylene were lost.

1985 TRICHLOROETHENE (TCE) LEAK

On January 23, 1985, Carrier experienced a second release of trichloroethylene as a result of a pipe failure associated with an above-ground tank holding trichloroethylene. An estimated 500 gallons were lost.

1.2.3 Previous Removal/Remedial Actions

Carrier Corporation has taken a number of steps to remove/eliminate sources of TCE and reduce the impact of prior releases. Following the 1979 spill, a large area of asphalt pavement and underlying soil was excavated and disposed offsite prior to repaving.

In 1980 the former lagoon was closed and sediment excavated and shipped off site for disposal. In 1989, Carrier installed a groundwater recovery and treatment system to remove TCE contaminated groundwater from the area of the former surface impoundment. This area has been designated as the North Remediation System (NRS), and also includes a Soil Vapor Extraction (SVE) system to removed vapors from TCE contaminated soils.

After the 1985 release, Carrier initiated a massive soil excavation and testing program to remove TCE and TCE contaminated soils from the impact area.

In 1990, Carrier and the town of Collierville designed and installed an air stripping tower system at the Well Field #2 Treatment Plant. This 1.5 million gallons/day (mgd) system removes TCE from raw water prior to entry into the chlorination system and allows the town to use Well Field #2 fully. The treatment system was designed to handle incoming TCE concentrations of up to 200 $\mu\text{g/l}$. Design, construction, and operation of this system was coordinated with and approved by the Tennessee Department of Water Supply (which permits water treatment systems), the Memphis-Shelby County Health Department, Bureau of Pollution Control (which has delegated

authority for air emissions permitting), the State of Tennessee Division of Superfund, and the town of Collierville. EPA, Region IV, was informed and concurred in the action. The treatment system is currently monitored at least quarterly for volatile organic compounds (VOCs), and initially, was monitored more frequently to establish system performance. No TCE has been detected in the town's treated water since installation of the system, at a method detection limit of 0.3 $\mu\text{g/l}$.

1.2.4 Geology and Physiography

The Memphis/Shelby County area is situated in two major physiographic subdivisions: the Mississippi Alluvial Plain and the Gulf Coastal Plain section. The Collierville site is located in the Gulf Coastal Plain section which is distinguished by gently rolling topography and a characteristic thick layer of loess deposited during Pleistocene glaciation. Anomalous areas of loess deposition are associated with the alluvial plains of Mississippi River tributaries that cross the area. These rivers include the Wolf River, the Loosahatchie River, and Nonconnah Creek. Nonconnah Creek runs through and adjacent to the Collierville site boundaries.

1.2.5 Hydrogeology

Unconsolidated deposits up to 3,000 feet deep overlie the bedrock in the Memphis/Shelby County area. The sediments consist principally of sand, clay, gravel, silt, and some lignite. The principal freshwater aquifers in the Memphis/Shelby County area are:

- Alluvium and Fluvial (terrace) deposits
- Memphis Sand
- Fort Pillow Sand

The alluvium and fluvial deposits are separated in most areas from the Memphis Sand by the Jackson-upper Claiborne confining layer (locally referred to as the Jackson Clay). The Memphis Sand and the Fort Pillow Sand are separated by the Flour Island confining layer.

SHALLOW GROUNDWATER

Two aquifer units have been identified for purposes of addressing site remediation: (1) intermittent shallow water in the alluvial and fluvial deposits overlying the Jackson Clay, and (2) the Memphis Sand aquifer. The intermittent presence of shallow groundwater is due to rainfall events in the surface of the Jackson Clay layer. These undulations capture and direct percolating groundwater to create shallow streams along the top of the clay layer. The clay surface slopes radially away from a high existing in the northwest portion of the site, resulting in radial movement of shallow groundwater away from the high.

MEMPHIS SAND GROUNDWATER

The Memphis Sand is a regressive thick-bedded sand unit deposited in near-shore to back-beach deltaic and alluvial environments. Regionally, the Memphis Sand consists of massive beds of fine to coarse grained well-rounded to sub-angular sand and gravels intercalated with thin lenses and beds of silt, clay and argillaceous, micaceous and lignitic materials [Moore, 1965; Hosman, et al. 1968]. Regionally, interbedded clay/silt layers are up to 20 feet thick but appear to have only a local affect on hydraulics in the Memphis Sand. General strike is N-NE, dip is to the west towards the Mississippi River and total thickness generally varies between 500-850 feet.

Locally, the aquifer piezometric surface indicates flow in the north to northwest direction.

1.3 SUMMARY OF NATURE AND EXTENT OF SOIL CONTAMINATION

1.3.1 Contaminants of Concern

Results of the Collierville site investigation show varying levels of TCE contamination on the property. Results from soil and groundwater sample analyses, and soil-vapor screening data confirm that the two spill areas and the former lagoon area are the sources of contamination of site soils and groundwater. Table 1-1 summarizes soil analytical data collected during the RI from 1990 to 1991. Samples were located for purposes of delineating source areas.

**TABLE 1-1
SUMMARY OF RI SOILS RESULTS**

Parameter	No. Samples	No. Hits	Range, µg/kg	Mean, µg/kg	Standard Deviation, µg/kg
TRICHLOROETHENE	56	8	8-1200000	152000	420000
1,2-DICHLOROETHENE	56	3	14-200	78	110
TETRACHLOROETHENE	56	1		11	
1,1,2-TRICHLOROETHANE	56	1		26	
TOLUENE	56	4	6-87	40	60
2-BUTANONE	56	1		190	
ACETONE	56	3	12-35	26	13
LEAD (mg/kg)	39	33	0.67-21.4	7	4
ZINC (mg/kg)	39	26	3.3-77.8	33	15

Soil samples collected within areas suspected to be impacted by spills indicate a wide range of levels of contamination. The vertical extent of TCE contamination is variable throughout the site. Soil screening methods indicate that many of the sample's concentration levels decrease with depth. However, there are samples which indicate an increase in concentrations as the zone of saturation in the shallow aquifer is approached. Soil samples collected from the former lagoon area confirm the presence of TCE near the zone of saturation.

Elevated levels of two metals, lead and zinc, were seen in shallow soils. Lead values range from 7 to 15 mg/kg. Lead and zinc values generally decrease with depth in all site soils.

1.3.2 Contaminant Distribution, Fate and Transport

There have been three documented sources of chlorinated hydrocarbon contamination at the Collierville site as described above. Residual contaminants from these source areas are still present in specific areas. Furthermore, TCE and its degradation products have been identified in groundwater. Groundwater contamination has been identified at the Collierville site in the shallow aquifer, and within the Memphis Sand aquifer. The mechanics for migration of TCE from the source areas to the aquifers depend on solvent-specific characteristics, site-specific geology and hydrogeology. Pure-phase TCE is characterized in the literature as an immiscible fluid with a density greater than that of water, and is classified as a dense non-aqueous-phase liquid (DNAPL) [Ram, *et al.* 1990].

Soil boring data demonstrate that TCE is migrating through the vadose zone. Residual solvent remains adsorbed within the pore space of the soil particles as TCE migrates through the soil. The total volume of fluid released may be stored in this "residual saturation" phase in the vadose zone unless the soil retention capacity has been reached. The actual distance of downward migration of the fluid phase becomes dependent upon the quantity of material released, the soil retention capacity and the thickness of the vadose zone. Pure phase TCE was not encountered during the investigation, implying that soil retention capacities are not exceeded on the site.

Further migration of TCE from soils occurs as vapor-phase diffusion through soil pores and as migration in the dissolved aqueous phase. TCE vapors have a density greater than air and transport to the shallow aquifer may be enhanced by density-induced advection in the gas phase [Ram, *et al.* 1990]. At the Collierville site, TCE appears to be reaching groundwater in the dissolved aqueous phase from the infiltration and percolation of rainwater through the soils, and through diffusion in the vapor phase.

1.4 SOILS REMEDIATION CRITERIA FOR GROUNDWATER PROTECTION

The following section summarizes the results of the Exposure Assessment Multimedia Model (MULTIMED) for use in determining soil clean-up levels necessary for the protection of groundwater. For more details concerning MULTIMED, refer to the Baseline Risk Assessment.

1.4.1 MULTIMED Application

MULTIMED was applied to estimated and calculated site-specific hydrologic and hydrogeologic conditions in conjunction with contaminant specific physical and chemical parameters. Site data was entered into four major categories - vadose zone variables, chemical variables, source variables, and aquifer variables.

Vadose zone variables were not required in the MULTIMED run because leachate concentrations were given at the shallow groundwater surface. Chemical variables were used to describe the type of contaminant to be modeled. For the Collierville site, the contaminant chosen was trichloroethylene. Source specific variables are used to describe the quality and quantity of contaminant being modeled, these variable include - infiltration rate, spread of contaminant source, recharge rate, initial concentration at the landfill, facility length, and facility width. Aquifer specific variables are used to describe the characteristics of the saturated zone. Aquifer data for the shallow groundwater above the Jackson Clay were used.

1.4.2 Soil Clean-Up Level

Target levels for soil clean-up were calculated using MULTIMED output in conjunction with data obtained during the RI. The target mean leachate concentration from MULTIMED was applied to the percolate volume per year, vertical hydraulic conductivity, thickness of the vadose zone, water mass balance coefficient, flushing coefficient, vadose zone porosity, and specific weight of the vadose soils to yield a target for soil clean-up.

The percolate volume per year is that volume of water which enters the vadose zone each year and is not lost to evaporation or runoff. Initial percolate volume calculations were based on the total site area, or 30 acres. These volumes were reduced to specific areas relating to the source areas, or 6.4 acres. Percolate volume calculations yielded a rate of approximately 145,000 cubic feet per year.

Vertical hydraulic conductivity through the vadose zone was estimated as one third of the horizontal hydraulic conductivity. This is due to the preference of shallow groundwater to follow horizontal rather than vertical flowpaths. A vertical hydraulic conductivity of 3.3 ft/yr

was calculated based on a horizontal hydraulic conductivity of 10 ft/yr obtained from tabulated values of soils representative of those at the site.

Thickness of the vadose zone was obtained from boring and monitoring well installation logs. Vadose zone volume was estimated as the product of the total area of the source zone, including paved areas, and the depth of the vadose zone.

The water mass balance coefficient was based on mass partitioning of solid, liquid, and vapor in the soil mass.

Porosity and specific weight of the soil were estimated from values obtained during soil boring and monitoring well installation during the RI.

Using the above data, the theoretical level for soil clean-up was calculated to be 533 $\mu\text{g/kg}$.

2.0 DESIGN CRITERIA REPORT

2.1 SOIL VOLUMES REQUIRING TREATMENT

Soils impacted by TCE releases around the MPA (1979 and 1985) are the subject of this report. Approximately 8300 cubic yards of contaminated soils in the former lagoon area are currently being remediated by SVE.

Table 2-1 depicts soil volumes contaminated with TCE at the MPA during RI activities. Each volume was measured by CLP volatile and screening method analyses of split-spoon soil boring samples from various depths. The product of resulting areas and depth intervals yields the following volumes of soil that are required for remediation based on RI data:

TABLE 2-1 SOIL VOLUMES >533 $\mu\text{g/kg}$ (RI Data)	
INTERVAL, ft	VOLUME, cubic yards
0 - 5	16,000
5 - 10	16,400
10 - 15	19,500
15 - 20	16,300

Soil samples analyzed for TCE during MPA drilling activities indicate that the soil volumes necessary for remediation may be smaller than volumes calculated using RI data. Soil volumes above 533 $\mu\text{g/kg}$ will be delineated during the drilling of additional SVE wells.

2.2 SVE TREATMENT OF CONTAMINATED SOILS

The following description of soil vapor extraction is excerpted from the revised final draft of the *Guide for Conducting Treatability Studies Under CERCLA: Soil-Vapor Extraction*, March 1, 1991, Foster-Wheeler Enviresponse, Inc.

The SVE process is a technique for the removal of VOCs from the vadose zone. In many instances the contaminants are dissolved in the water that fills the interstices between soil particles. Equilibrium between the contaminant in aqueous solution and that in associated vapor is governed by Henry's Law.

The dynamics of SVE are characterized as follows. When air is drawn through the soil, it passes through a series of pores, most readily following paths of lower resistance (through zones of high air permeability). Air that is drawn through pores that contain contaminated vapor and liquids will carry vapor away (advect the vapors). Contaminants will vaporize from one or more of the condensed phases (organic, aqueous, adsorbed) replacing vapors that were carried away in the air stream. Contaminants in lower permeability zones will not be removed by advection since the air stream will continue to flow through spaces of higher permeability. If the contamination is located at some distance from the air flow, the vapor must diffuse to the air stream before it can be carried away.

Vacuum pumps or blowers reduce gas pressure in extraction wells and induce subsurface air flow toward the wells. The subsurface induced vacuum causes formation of a pressure gradient. This gradient ideally covers a circular area (around the extraction well screen). The distance from the well out to the perimeter of appreciable pressure gradient is called the radius of influence. In other terms, the radius of influence is the radial distance from the extraction well that has adequate air flow for effective removal of contaminants. Hence the radius of influence and areal extent of contamination determine the number of extraction wells required at a given site.

2.2.1 SVE at the MPA

In general, configuration of the MPA source remediation system will mimic that of the NRS. Geologic setting, the nature of contamination near the manufacturing plant buildings, and treatability work at the NRS indicate that MPA SVE implementation will entail a two-tiered approach. Shallow, heavily contaminated soils may require installation of horizontal SVE

galleries. Contamination that has migrated downward to the Jackson Clay, and residual TCE in overlying silts and sands would best be addressed with vertical extraction wells screened throughout the contaminated zone.

The locations and number of vapor extraction wells necessary to meet Remedial Action Objectives (RAOs) at the Collierville site is dependent upon the areal extent of contamination, area of influence produced by each well, and variability in pneumatic permeability around the plant area. A surface cover may be a consideration to prevent short-circuiting and enhance the vacuuming of TCE vapors. Short circuiting occurs when an inflow of air from the surface is induced from the SVE system, in turn, decreasing the area of influence. A portion of the MPA has asphalt surfaces above source areas.

The implementation of SVE at the MPA is technically feasible, and the system can be installed at the site with a minimum of disturbance. Specific soil characteristics, *e.g.*, soil permeability, moisture content, and grain size analysis, are required to determine optimal design parameters.

Pre-screening results and PET results indicate that soil contamination above the cleanup criteria of 533 $\mu\text{g/kg}$ may not exist in the deep zone. Confirmation of the preliminary results will be obtained during the drilling of additional SVE wells. Additional deep borings will be advanced based on the triangular spacing pattern outlined in the workplan, at the same time shallow soil contamination will be delineated. If deep soils analysis is above the cleanup criteria, a deep SVE extraction well will be installed.

2.2.2 Off Gas Treatment of Vapor-Phase Contaminants

Vapor-phase contaminants are produced as a result of SVE. To minimize risk to onsite workers and the surrounding community, and to comply with the Clean Air Act per the FS, off-gas emission controls will be necessary and attained through the use of either granular activated carbon (GAC) adsorption or thermal incineration. These two options will be considered in more detail during pre-final design. Cost efficiency over the life of the project will be the determining factor in choosing an emission control device. Controls would assure that adverse impact on the environment during implementation of SVE would be negligible.

Emissions from the SVE pilot study were monitored and sampled to predict TCE loading rates produced during full-scale SVE remediation. Vapor-phase samples were withdrawn prior to entry into the GAC canister from both deep and shallow extraction wells at all three source areas. Results indicate that high vapor-phase concentrations of TCE exist in the deep, more permeable soils versus lower vapor-phase concentrations in the shallow, less permeable soils. As expected, TCE was the dominant constituent in off-gas emissions and will be the driving constituent in off-gas emission control design as well as the maximum permissible amount of TCE allowed to be discharged to the air of 3 lbs/day, 15 lbs/day, 10 tons/year (OSWER Directive 9355.0-28). Vinyl chloride was detected in one sample and will also be considered in emission control design. Detailed results of emissions produced during the pilot study are discussed in Section 2.4 of this report.

2.3 SVE INPUT/OUTPUT RATES

Emission discharge rates were calculated from field test data. These loading rates range from 0.0031 lb/day to 0.0183 lb/day of TCE in the shallow soils and 0.0174 lb/day to 11.4 lb/day TCE in the deep soils. Input rates during full scale operation cannot be estimated at this time without knowledge of the actual number of SVE extraction wells needed.

Output rates cannot be estimated without knowing the number of SVE extraction wells that will be installed. Emission control devices will be employed during full scale operation, and TCE emission discharge rates will be below stated maximums.

2.4 INFLUENT AND EFFLUENT QUALITIES

As stated in Section 2.2.2, vapor-phase samples were taken during the SVE pilot scale treatability test. Table 2-1 is a summary of the results of effluent sampling during the pilot scale test, and results indicate only those constituents which were above detection limits in at least one sample. Time designations beside each sample identification indicate the elapsed time into the test at which the sample was withdrawn. Samples were designated as follows:

- 1A1 SVE extraction well #1, Area A, sample #1
- 2B2 SVE extraction well #2, Area B, sample #2

(odd nos. designate deep wells, even nos. - shallow)

where:

Area A: Southeast of MPA, occurred as a result of washwater used to push TCE from 1979 spill area.

Area B: 1979 TCE spill area.

Area C: 1985 TCE leak area.

<p style="text-align: center;">TABLE 2-1 ANALYSES OF SOIL VAPOR (EPA METHOD 8010) (all results in $\mu\text{g/l-vapor}$)</p>					
Sample I.D.	TCE	1,2 cis Dichloroethene	1,2 trans Dichloroethene	1,1 Dichloroethene	Vinyl Chloride
1A1 (20 min)	ND	ND	ND	ND	ND
1A2 (45 min)	0.7	ND	ND	ND	ND
1A3 (60 min)	2.5	ND	ND	ND	ND
2A1 (60 min)	ND	ND	ND	ND	ND
2A2 (90 min)	ND	ND	ND	ND	ND
1B1 (30 min)	1250	76.8	0.6	6.3	4.2
2B1 (30 min)	3.0	ND	ND	ND	ND
2B2 (60 min)	2.7	ND	ND	ND	ND
2B3 (90 min)	3.5	ND	ND	ND	ND
2C1 (45 min)	0.6	ND	ND	ND	ND
2C2 (60 min)	ND	ND	ND	ND	ND
1C1 (10 min)	1640	3.7	ND	ND	ND
1C2 (45 min)	840	1.8	ND	ND	ND
ND indicates not detected at detection limit of 0.5 $\mu\text{g/l-vapor}$ for each compound.					

Table 2-1 gives an indication of the constituents that can be expected during SVE at each source area.

Remedial alternatives, such as SVE, which involve the potential emission of VOCs as potential precursors to atmospheric ozone production, are subject to regulations which require emission controls. EPA guidance for Superfund remediation (OSWER Directive 9355.0-28) specifically addresses soil-vapor extraction pumps located in ozone non-attainment areas. In particular, the directive states that the following emissions limit goals, established in guidance entitled *Issues Relating to VOC Regulation Cutpoints, Deficiencies, and Deviations*, issued in May 1988 by the Office of Air Quality Planning and Standards, be used in determining the need for emission controls on point-source vents of VOCs. This is intended to be protective of air quality in ozone non-attainment areas, where controls may not be mandated at this emission level.

The basis is any facility with the potential to emit above the following thresholds:

- 3 lbs/hr
- 15 lbs/day
- 10 tons/yr based on 24 hr/day, 365 days/yr operations

For purposes of the Collierville site MPA, the above thresholds shall not be exceeded for TCE.

In addition, the EPA has established emissions standards for sources of eight pollutants considered to be carcinogenic or mutagenic hazards. The substances covered by these standards, are arsenic (inorganic), asbestos, beryllium, mercury, vinyl chloride, benzene, radon-222, and radionuclides. One of these pollutants, vinyl chloride, has been detected in vapor phase samples, but at a level lower than the standard set by National Emission Standards for Hazardous Air Pollutants (NESHAPS) of 10 parts per million (ppm).

2.5 EVALUATIONS CONDUCTED TO SELECT THE DESIGN APPROACH

The design approach is intended to fully implement the selected remedy as described in the Record of Decision (ROD) for the Collierville site, and to achieve the Performance Standards

set forth in the ROD. The primary objective that was considered when evaluating the proper design approach was to prevent migration of contaminants from soils that cause the Memphis Sand aquifer groundwater to exceed Maximum Contaminant Levels (MCLs).

To evaluate the proper remedial action necessary to obtain the primary objective in an efficient and cost effective manner, a Feasibility Study (FS) was conducted to develop and evaluate a range of applicable alternatives for site remediation, and present the EPA with a basis for choosing among them. The remedial alternatives assembled during the FS focused on the pathway of TCE migration in soils and groundwater and the resultant risks of exposure. The FS identified a range of treatment and containment technologies, and screened non-applicable, or less promising technologies from consideration. The assembled alternatives were then evaluated against criteria listed in the National Contingency Plan, and compared. SVE was identified as an alternative, and selected as the remedial action to be applied in areas impacted by spills around the MPA. The goal is to bring contaminant concentrations in soil to a level protective of Memphis Sand groundwater, 533 $\mu\text{g/l}$.

Factors which were considered in evaluating the design approach:

- Minimize site disturbance during construction phase
- Minimize risk to plant workers by utilizing off-gas emission controls if needed
- Field design the SVE system by delineating shallow and deep soil contamination based on cleanup criteria

2.6 MATERIALS AND EQUIPMENT

2.6.1 SVE Extraction Wells and Monitoring Points

SVE extraction wells will be constructed in the same manner as those installed during the SVE pilot scale treatability test, and as illustrated in the *Guide for Conducting Treatability Studies under CERCLA: Soil Vapor Extraction. Interim Guidance*, September 1991, USEPA. Each SVE extraction well will be converted from soil borings using slotted PVC pipe. A medium to

coarse-grained filter pack will be installed around the screen interval with a 2-foot bentonite seal on top of the sand pack. The bentonite seal will be allowed to hydrate at least 24 hours before a cement/bentonite grout seal is used to fill the remaining annular space.

Any additional monitoring points will be constructed in the same manner, with the exception of using a 1" ID Schedule 40 PVC pipe.

2.6.2 Vacuum Pump

The vacuum pump size will be determined by the required air-flow rate and vacuum level. Based on results of the PETs, different vacuum sources should be used for the deep extraction wells and the shallow extraction wells. Deep extraction wells, screened in relatively higher permeability soils, should use a high volume, low pressure blower. The shallow wells, screened in lower permeability soils, should use a low volume, high pressure blower. Deep extraction wells, showed almost immediate response at corresponding monitoring probes, therefore, a high volume blower is best suited for this type of formation. The shallow extraction wells did not show an immediate response at the corresponding monitoring probes due to the low permeability soils in which the wells were screened through. Differing blower designs and separate manifolds will likely be needed for the most effective overall system.

2.6.3 Vapor/Liquid Separator

Although no measurable amount of liquid was entrained by the blower during the PETs, it is common to provide a vapor/liquid separator prior to each vacuum blower to prevent groundwater being ingested into the blowers as a result of rising water tables during high rainfall periods. Should carbon adsorption be used for off-gas emission control, use of a vapor/liquid separator, and a mist eliminator, should reduce carbon usage significantly.

2.6.4 Surface Seals

The need for surface seals is determined by the air-flow distributions and the potential for surface water infiltration. Data from the PETs, indicate no significant difference in air permeability between areas which have no surface seals (Area A and C), and Area B.

2.6.5 Off-gas Emission Control

As stated earlier, the maximum amount of TCE that can be emitted to the atmosphere is 3 lb/hr, 15 lbs/day, or 10 tons/yr. Results of the PETs indicate that these limits will be exceeded, and off-gas emission control will be needed.

2.7 PERFORMANCE STANDARDS

Performance Standards can be found in Section 9.1 of the *Carrier Air Conditioning Superfund Site Record of Decision*.

2.8 DECISION RULES

As stated in the ROD, the cleanup criteria for soil is 533 $\mu\text{g/kg}$. This number was calculated using MULTIMED. The model was used in conjunction with traditional contaminant mass partitioning formulae to determine the soil cleanup goals necessary for protection of groundwater in the Memphis Sands.

There were no concentrations above 533 $\mu\text{g/kg}$ obtained from soils in the deep zone. All concentrations above 533 $\mu\text{g/kg}$ were obtained in soils ranging from 2 to 13 feet below ground level. Based on these results, the drilling of additional SVE extraction wells will be concentrated on the delineation of shallow contaminated soils in all source areas. Deep well borings will still be advanced to confirm that soils above 533 $\mu\text{g/kg}$ exist. Shallow soils will be delineated while advancing deep borings. The pattern of widely spaced deep well borings may not be sufficient to delineate shallow soil contamination, in this case, additional borings limited to the shallow zone will be required. Preliminary results indicate that deep soil contamination may not be a problem, but a vapor plume does exist in the deep soils.

Higher concentrations were expected during drilling activities in Area A, based on soil sampling results from the RI. To confirm or deny the existence of soil contamination above 533 $\mu\text{g/kg}$ in this area, borings will be placed just south of Area A, towards Nonconnah Creek.

2.9 LONG TERM MONITORING REQUIREMENTS

A program of soil gas monitoring will be initiated to assure that contaminant diffusion from zones treated during remediation is not occurring. Soil gas monitoring will consist of withdrawing soil vapor at each source area to estimate when the SVE system can be shut off to allow vapor equilibrium. The system will then be reactivated and operated until soil gas concentrations are again reduced to asymptotic levels. A confirmatory soil boring program will then be performed to see if soils meet performance standards.

2.10 RESULTS OF THE SVE TREATABILITY TEST

Included in Appendix A is the MPA SVE Treatability Test Report for the Collierville Site.

3.0 PRELIMINARY PLANS AND SPECIFICATIONS

The following is an outline of the proposed drawings to be developed and submitted in order to implement the full scale SVE system at the MPA.

- Site Plan - The site plan will give an overview of the complete MPA SVE system, including, brief descriptions of all equipment to be used and their locations, proposed trenching locations, locations of SVE extraction wells/galleries, and existing underground and overhead utilities. The site plan will also depict electrical line runs from power sources to equipment.
- Mechanical Details - This drawing will include schematics of all equipment and associated piping, schematic of the SVE extraction wells/galleries, fencing details (if needed), and cross-sections of trenching through asphalt, concrete, and grassy areas.
- Electrical Diagrams - This drawing will include a single line diagram depicting panel wiring, blower wiring, fail-safe relay wiring, and power feed to new equipment.
- Process & Instrumentation Diagram - This diagram is a symbol schematic drawing of the entire MPA SVE process. Included in the diagram are, line dimensions, flow directions, fail-safe switches, and necessary valves.

4.0 PLAN FOR SATISFYING PERMITTING REQUIREMENTS

As stated in the ROD, all activities must be performed in accordance with the requirements of all applicable federal and state laws and regulations.

The following is a list of activities that will/will not require a permit while constructing the MPA SVE system and operating the system.

- Drilling/Trenching Activities - At the Collierville Site, no off-site disposal action is proposed. All residuals from MPA drilling activities and residuals resulting from future drilling and trenching activities will remain onsite and be implemented into the full scale SVE system at the MPA. This is done in compliance with 40 CFR 300.400, which states:

No federal, state, or local permits are required for on-site response actions conducted pursuant to CERCLA sections 104, 106, 120, 121, or 122. The term on-site means the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action.

- Construction - Shelby County will require a construction permit prior to any construction activities at the site. Time to process the permit is approximately 3 months.
- Air Emissions - Pursuant to OSWER Directive 9355.0-28, the maximum amount of TCE allowed to be discharged to the air is 3 lbs/hr, 15 lbs/day, 10 tons/year. Based on the calculated emission rates obtained from PET data, during full-scale SVE operation this limit will be exceeded. Memphis-Shelby County Health Department, Air Engineering Department, requires a permit to construct and a permit to operate a system for discharge of any VOC to the atmosphere. The process time for this permit is approximately 3 months.

5.0 DRAFT CONSTRUCTION SCHEDULE

The draft schedule for construction and implementation of the remedial action is shown below.

<u>Task Name</u>	<u>Start Date</u>	<u>End Date</u>	<u>Duration</u>
Preliminary Design Submittal	9-Jan-94	9-Jan-94	1 day
Preliminary Design Approval	9-Jan-94	9-March-94	60 days
Install Additional SVE Wells	11-Mar-94	9-Apr-94	30 days
Complete Design Analyses	10-Apr-94	14-May-94	35 days
Final Plans/Specifications	15-May-94	1-Aug-94	78 days
Final Construction Schedule	15-May-94	1-Aug-94	78 days
Construction Cost Estimate	15-May-94	1-Aug-94	78 days
SVE Performance Verification	15-May-94	1-Aug-94	78 days
Submit Final Design Documents	31-Aug-94	31-Aug-94	1 day
EPA Review and Approval	31-Aug-94	27-Nov-94	89 days
RA Workplan Submit/Approval	11-Feb-95	10-May-95	89 days
Contractor Selection	11-May-95	24-Jun-95	45 days
Equipment Order	11-May-95	11-Jul-95	62 days
Preconstruction Conference	25-Jul-95	25-Jul-95	1 day
Construction	9-Aug-95	7-Oct-95	60 days
Prefinal Construction Inspection	15-Oct-95	15-Oct-95	1 day
Final Inspection	15-Nov-95	15-Nov-95	1 day

These dates are contingent upon EPA review time.

A

APPENDIX A

MPA TREATABILITY STUDY REPORT-SOIL VAPOR EXTRACTION

**CARRIER COLLIERVILLE SITE
DRAFT MAIN PLANT AREA TREATABILITY STUDY REPORT
SOIL VAPOR EXTRACTION**

**Prepared for:
Carrier Corporation
97 South Byhalia Road
Collierville, Tennessee 38017**

**Prepared by:
Environmental and Safety Designs, Inc.
5724 Summer Trees Drive
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JANUARY 7, 1993

Table of Contents

1.0	EXECUTIVE SUMMARY	1
2.0	TREATABILITY STUDY APPROACH	3
2.1	TEST OBJECTIVES AND RATIONALE	3
2.2	EXPERIMENTAL DESIGN AND PROCEDURES	4
2.2.1	MPA Drilling Activities	4
2.2.2	MPA Parameter Evaluation Testing	6
2.3	EQUIPMENT AND MATERIALS	7
2.4	SAMPLING AND ANALYSIS	8
2.4.1	Soils	8
2.4.2	Treatment Process	8
3.0	RESULTS	10
3.1	DATA ANALYSIS	10
3.1.1	Analysis of Soils and Soil Vapor	10
3.1.2	Analysis of Treatability Study Data	15
3.1.3	Comparison to Test Objectives	20
4.0	CONCLUSIONS AND RECOMMENDATIONS	22

List of Figures

Figure 2-1	SVE Well and Probe Locations	5
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List of Appendices

Appendix A	Shelby Tube Sample Analytical Reports
Appendix B	SVE Well/Monitoring Point Layout Figures
Appendix C	Woodson-Tenent Analytical Reports
Appendix D	TransGlobal Environmental Geochemistry Analytical Reports
Appendix E	TransGlobal Environmental Geochemistry/Kabis Environmental Services SVE Report
Appendix F	Emission Rate Calculations
Appendix G	Pneumatic Permeability Calculations
Appendix H	Effective Radius of Influence Calculations

1.0 EXECUTIVE SUMMARY

A Parameter Evaluation Test (PET) was conducted at the Carrier Collierville Site in three separate source areas to demonstrate the feasibility of utilizing vacuum extraction as the remedial technology at the Main Plant Area (MPA). The objectives of the PETs were to confirm the status of TCE contaminated soils as described in the Remedial Investigation/Feasibility Study (RI/FS), determine the air permeability of the shallow, silty clay zone and the deeper, sandy soils, evaluate treatment options based on air emission discharge rates, and determine site specific design criteria for a full-scale vacuum extraction system.

The PETs were initiated on December 1, 1993 and concluded on December 2, 1993 for a total system operating time of 15 hours.

During each PET, vacuum levels of 41 to 54 inches of water were applied to shallow and deep extraction wells at each source area. These applied vacuums produced extracted vapor flowrates from 60 to 80 cfm with subsurface vapor flowrates up to 4.56 cfm/ft screen in the sandy zone measured 32 feet away from deep extraction wells and subsurface vapor flowrates up to 0.0012 cfm/ft screen in the silty clay zone measured 23 feet away from shallow extraction wells.

When comparing the results of the shallow and deep soil PETs, it is evident that the resulting vacuum influence from extracting soil gas from the deep extraction wells results in a larger radial influence and contaminant removal rate. Results of sampling analysis during MPA SVE drilling activities indicate that no soils above the cleanup criteria of 533 $\mu\text{g/kg}$ were encountered in the deep zone, but were encountered at depths ranging from 2 to 13 feet below ground level.

Based on these results, additional SVE drilling activities will concentrate on the delineation of the shallow soil contamination and a confirmation of soil concentrations in the deep zone. Although no soil results above 533 $\mu\text{g/kg}$ were encountered in the deep zone, extraction should be performed at this depth on a limited basis to contain and remove the vapor plume.

Table 1-1 is a summary of the key findings at each source area during PETs.

TABLE 1-1 PET SUMMARY				
Area	Effective Radius of Influence (ft)	Average Horizontal Permeability (cm ²)	TCE Removal Rate (lb/day)	Vacuum at Wellhead (in. H ₂ O)
A, Shallow	15 - 25	2.5×10^{-13}	0	47
A, Deep	55 - 65	3.7×10^{-8}	0.017	47
B, Shallow	15 - 20	1.9×10^{-12}	0.018	54
B, Deep	100 - 120	3.7×10^{-8}	8.71	41
C, Shallow	30 - 50	2.2×10^{-6}	0.003	54
C, Deep	50 - 100	3.1	11.43	41

2.0 TREATABILITY STUDY APPROACH

Refer to Preliminary Design Report for site history and description.

Soil Vapor Extraction (SVE) is used for the remediation of soils contaminated with volatile organic compounds (VOCs). The vacuum extraction process is a technique for the removal and venting of VOCs from the vadose or unsaturated zone of soils. A vacuum system induces air flow through the soil, stripping and volatilizing the VOCs from the soil matrix into the air stream. The contaminated air stream then flows through off-gas treatment.

The purpose of a SVE Treatability Study is to obtain data regarding expected flow rates, soil pressure fields, and emission concentrations to be used in the design of a full-scale SVE system. Typical results often include plots of pressure drop in the soil zone versus distance from a pressure sink (SVE extraction well), measured concentration of target compounds in the exhaust gas, and effective radius of influence of a SVE extraction well.

SVE field pilot tests are small scale tests typically conducted prior to design of full-scale SVE systems to assess soil permeability to gas, vapor flow rates, subsurface vacuum distribution, contaminant concentration locations, etc. This information can then be used in SVE remediation modeling to determine SVE design parameters such as contaminant removal rates, effective radius of influence, the design wellhead vacuum, and total system vapor flow rate.

2.1 TEST OBJECTIVES AND RATIONALE

Soils containing varying concentrations of VOCs can be remediated using the mass-transfer technique of SVE. The feasibility and design of such remedial systems, however, requires information regarding the in-situ contaminant characteristics, concentration, and formational flow characteristics. To acquire this data, SVE field pilot testing is conducted. The following are objectives which are vital to the design and operation of the MPA SVE system:

- Confirm the status of TCE contaminated soils as described in the RI/FS.

- Obtain SVE design parameters such as soil permeability and pressure thresholds.
- Gather data needed to evaluate treatment options for air emissions.
- Determine site specific design criteria for a full scale vacuum extraction system.

2.2 EXPERIMENTAL DESIGN AND PROCEDURES

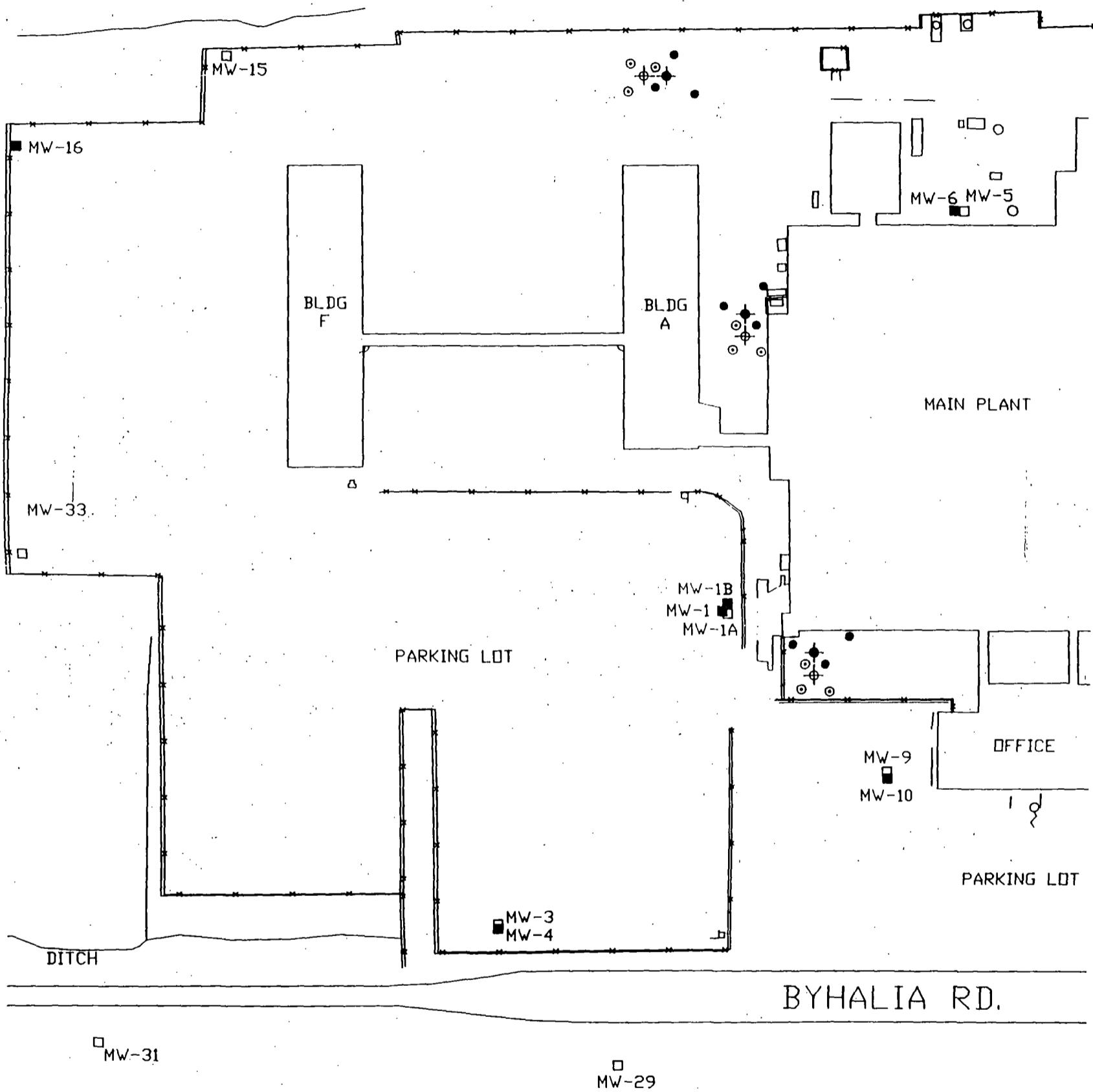
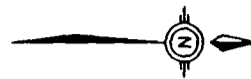
2.2.1 MPA Drilling Activities

Three areas were identified during the RI/FS as source areas of TCE contamination at the MPA, the 1979 spill area was located on the south side of the MPA, the 1985 leak area is located east side of the MPA, and the third area is located southeast of the MPA and occurred as a result of fire department response activities when wash water was used to push TCE from the 1979 spill area. Each area was designated with a letter to aid in drilling and sampling activities. These designations are as follows:

- Area A - 1979 spill, west of Building F.
- Area B - 1979 spill, south of main manufacturing building.
- Area C - 1985 leak, east of main manufacturing building.

Figure 2-1 shows the locations of each area.

One deep and one shallow SVE 2" ID Schedule 40 PVC extraction well was installed in each area. For each SVE extraction well, three 1" ID Schedule 40 PVC SVE probes were installed at varying distances away from its respective SVE extraction well to measure vacuum influence. Shelby Tube samples were obtained from Area B (shallow, 13-15 ft), Area B (deep, 32-33 ft), and Area C (shallow 13-15 ft). Shelby tube samples from other areas were not obtainable due to no recovery in the tube. Analytical results of shelby tube samples can be found in Appendix A.



125 0 125
scale feet

LEGEND

- ⊕ - SHALLOW SVE WELL
- ◆ - DEEP SVE WELL
- ⊙ - SHALLOW SVE PROBE
- - DEEP SVE PROBE
- - MONITORING WELL

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FIGURE 3-1
PROPOSED SVE WELL
AND PROBE LOCATIONS
COLLIERVILLE SITE

DWG DATE: 04/29/93 DWG NAME: CARAREA5

2.2.2 MPA Parameter Evaluation Testing

Three SVE PETs were conducted at the MPA, one PET per designated area. Each PET was further broken down into separate PETs for the shallow SVE extraction well and the deep SVE extraction well. PETs were performed by using a blower to extract soil vapor through each SVE extraction well while monitoring pressure changes in the nearby SVE probes. Appendix B includes figures showing the layout of SVE extraction wells and monitoring probes at each area.

PETs at the Collierville site were conducted using a one-point standard test. Each SVE extraction well was placed under a constant vacuum at time zero (0). Within approximately 30 minutes from time 0, the surrounding SVE probes were monitored for vacuum inductance using a sensitive magnehelic gauge. The readings from each SVE probe were recorded every 30 minutes until apparent stability. Maximum vacuum and flow obtainable at each SVE extraction point was measured by completely closing the dilution air source. To further evaluate the flow in the subsurface, magnehelic gauge readings were recorded every 10 minutes, or less depending upon how immediate response occurred, this data was used to evaluate permeability to vapor flow. Soil vapor samples were withdrawn at regular intervals and analyzed, on-site for trichloroethylene, 1,1,1 trichloroethane, 1,1,1 trichloroethene, dichloroethane, vinyl chloride, and the degradation products of these contaminants. The frequency of soil vapor sampling was dependent upon response time at the SVE probe locations.

2.3 EQUIPMENT AND MATERIALS

SVE WELLS AND MONITORING PROBES

Each SVE extraction well is constructed of 2" ID Schedule 40 PVC, consisting of ten feet of 0.010-inch slotted screen. Clean, No. 30 silica sand is used as a sand pack around the screened portions of each well. Granular, hydrated bentonite was placed on top of the silica sand, and the remaining annulus sealed with a cement-bentonite grout seal. Each SVE probe is constructed in the same manner, with the exception of being 1" ID and containing 2.5 feet of screened section.

VACUUM SOURCE TEST BED

A rotary-vane, regenerative blower, capable of generating a vacuum equivalent to approximately 128 cubic feet per minute (CFM) at 70 inches of water, was mounted to a 4-foot by 5-foot tote-trailer. The blower was powered with a 2.8 hp, 100 VAC electric motor, wired to single-phase operation. The blower/compressor was constructed from cast iron and was equipped with an aluminum rotary vane to preclude the potential for spark production in a potentially explosive environment. The blower was plumbed to a 30-gallon granular activated carbon (GAC) canister at the vacuum side. A vacuum gauge calibrated to a full-scale reading of 400 inches of water was installed between the GAC canister and the blower; the vacuum was regulated using a single ball-valve choke mounted in-line with the vacuum gauge. The GAC canister was plumbed to the SVE extraction well under test. The exhaust, after GAC scrubbing, was vented to the atmosphere at approximately 9 feet above ground level. Power for the test bed was supplied by a 4kW gasoline-powered generator mounted to the trailer.

MOBILE LABORATORY

The TEG mobile laboratory consisted of the following equipment:

- Instrument - Shimadzu GC-14 Gas Chromatograph
- Column - 75 meter DB-624, megabore capillary
- Carrier flow - Helium at 15 ml/min.

- Detectors - Photoionization/Hall (EICD) detectors in series
- Detectors - Flame ionization detector on separate column

2.4 SAMPLING AND ANALYSIS

2.4.1 Soils

Soil samples were collected during MPA drilling activities using a continuous split-spoon sampler collected ahead of the augers at 10-foot intervals. Each sample core was visually inspected and recorded for lithology and field screened with a photoionization detector. Each sample was placed in pre-cleaned glass jars with septum lids for submittal to Woodson-Tenent Laboratories for VOC analysis by the co-distillation method approved for this site by the USEPA during the RI.

All soil samples were stored in a cooler containing ice placed in sealable plastic bags to provide temperature preservation at 4°C. All samples shipped for analysis were delivered to the laboratory within 24 hours of collection.

2.4.2 Treatment Process

Soil vapor was withdrawn from the intake manifold prior to entry into the GAC canister through a standard septum, using a 20 ml syringe connected via an on-off valve. The first 40 ml of gas were discarded to flush the syringe and fill it with in-situ soil vapor. The next 20 ml of gas were withdrawn in the syringe, plugged, and immediately transferred to the mobile laboratory for analysis within minutes of collection. Soil vapor samples were withdrawn from the sampling syringe with a 1 ml syringe and injected directly into a sampling port on the gas chromatograph. Injection syringes were baked between injections and discarded if values greater than 100 ppmv of any compound were measured.

All 8010/8020 analyses were performed with PID/Hall detectors in series on parallel 60 to 100 meter columns following EPA Method 8021 protocols. This configuration gives required separation and dual-detector confirmation.

Sample blanks were analyzed at the start of the day and more often as appropriate depending upon the measured concentrations.

3.0 RESULTS

3.1 DATA ANALYSIS

Treatability study data was interpreted to evaluate the distribution of TCE contamination in areas tested, assess air permeabilities in the vadose zone, estimate contaminant loading rates, and aid in the design of a full-scale SVE system capable of achieving cleanup criteria set forth by the Record of Decision (ROD) in a cost effective time.

3.1.1 Analysis of Soils and Soil Vapor

As described in Section 2.4, soil and soil vapor samples were collected during the treatability study. Analysis of these results will define areas of higher and lower relative TCE contamination. Tables 3-1, 3-2, and 3-3 are a summary of soil sampling events during MPA drilling activities in areas A, B, and C respectively. Woodson-Tenent laboratory analysis reports are included in Appendix C.

Only Area B contained sample results above the 533 $\mu\text{g/kg}$ criteria, which were located from depths ranging 2 to 13 feet below grade level.

TABLE 3-1 SOILS RESULTS, AREA A			
IDENTIFICATION	SVE WELL/PROBE	SAMPLE DEPTH (ft)	TCE (ppb)
CC-SVE-1A	Well	8-9	118
		18-19	72
		29-30	13
CC-SVE-2A	Well	4-5	53
		13-14	26
CC-MP-3A	Probe	8-9	< 10
		31-32	< 10
CC-MP-4A	Probe	ns	ns
CC-MP-5A	Probe	ns	ns
CC-MP-6A	Probe	ns	ns
CC-MP-7A	Probe	2-3	< 10
		27-28	< 10
CC-MP-8A	Probe	ns	ns

TABLE 3-2 SOILS RESULTS, AREA B			
IDENTIFICATION	SVE WELL/PROBE	SAMPLE DEPTH (ft)	TCE (ppb)
CC-SVE-1B	Well	2-3	548
		12-13	26
		22-23	38
		32-33	10
		39-40	38
		42-43	40
CC-SVE-2B	Well	2-3	1,600
		7-8	2,400
		12-13	650
CC-MP-3B	Probe	7-8	42
		32-33	< 10
CC-MP-4B	Probe	ns	ns
CC-MP-5B	Probe	ns	ns
CC-MP-6B	Probe	12-13	850
		14-15	360
CC-MP-7B	Probe	5.5-6.5	250
		22-23	35
		32-33	19
CC-MP-8B	Probe	14.4-15.5	60

TABLE 3-3 SOILS RESULTS, AREA C			
IDENTIFICATION	SVE WELL/PROBE	SAMPLE DEPTH (ft)	TCE (ppb)
CC-SVE-1C	Well	2-3	80
		12-13	72
		19-20	51
		22-23	34
		32-33	12
CC-SVE-2C	Well	2-3	116
		12-13	63
		22-23	29
CC-MP-3C	Probe	28-29	< 10
		32-33	< 10
CC-MP-4C	Probe	17-18	102
CC-MP-5C	Probe	ns	ns
CC-MP-6C	Probe	17-18	70
CC-MP-7C	Probe	22-23	< 10
		36-37	12
CC-MP-8C	Probe	12-13	317

Table 3-4 is a summary of the soil vapor concentrations extracted from each area during each PET. Only those constituents which had exhibited levels above non-detect in at least one sample are included in the table.

<p style="text-align: center;">TABLE 3-4 ANALYSES OF SOIL VAPOR (all results in $\mu\text{g/l-vapor}$)</p>					
Sample I.D.	TCE	1,2 cis Dichloroethene	1,2 trans Dichloroethene	1,1 Dichloroethene	Vinyl Chloride
1A1 (20 min)	ND	ND	ND	ND	ND
1A2 (45 min)	0.7	ND	ND	ND	ND
1A3 (60 min)	2.5	ND	ND	ND	ND
2A1 (60 min)	ND	ND	ND	ND	ND
2A2 (90 min)	ND	ND	ND	ND	ND
1B1 (30 min)	1250	76.8	0.6	6.3	4.2
2B1 (30 min)	3.0	ND	ND	ND	ND
2B2 (60 min)	2.7	ND	ND	ND	ND
2B3 (90 min)	3.5	ND	ND	ND	ND
2C1 (45 min)	0.6	ND	ND	ND	ND
2C2 (60 min)	ND	ND	ND	ND	ND
1C1 (10 min)	1640	3.7	ND	ND	ND
1C2 (45 min)	840	1.8	ND	ND	ND
ND indicates not detected at detection limit of 0.5 $\mu\text{g/l-vapor}$ for each compound					

The elapsed time into the test at which each sample was taken is noted next to the sample identification. The highest vapor concentration levels were obtained from sample 1B1, located at Area B in a deep SVE extraction well. This is the source area resulting from the 1979 TCE spill. The lower vapor concentration levels came from the shallow extraction wells, even though soil sample results from drilling activities indicate that soils in the shallow zone contain the highest levels of TCE as opposed to soils in the deeper zone. This is due to the relatively low permeability of the shallow soils not allowing air flow from the vacuum source as readily as the

higher permeability soils. TEG analytical reports of soil vapor concentrations are included in Appendix D.

3.1.2 Analysis of Treatability Study Data

A treatability study of SVE was conducted at the Carrier Air Conditioning Superfund Site, Collierville, Tennessee to demonstrate the feasibility of utilizing vacuum extraction as a remedial technology at the MPA. The objectives of the vacuum extraction field pilot test were to determine the air permeability of the upper silty clay unit and the lower sand unit, determine the effective radius of influence in each unit, and provide site specific information necessary for design of a cost effective full-scale SVE system.

The SVE pilot test operations were initiated on December 1, 1993 and concluded on the same day. Transglobal Environmental Geochemistry (TEG) was subcontracted to perform each PET and provide on-site analytical services for the test. A report of their findings during the test can be found in Appendix E. Additional test information was acquired by EnSafe personnel to evaluate air permeability and radius of influence at each area.

DATA COLLECTION

Several parameters were recorded during each PET. The parameters recorded were the applied vacuum, VOC concentration (by mobile laboratory on site), vacuum response at each monitoring location, as well as the time that the readings were taken.

VACUUM LEVELS/FLOWRATES

The vacuum levels applied to each SVE extraction well varied from 41 to 54 inches of water. These applied vacuums produced subsurface vapor flowrates ranging from 7.38×10^{-6} cfm/ft screen to 2.0×10^{-3} cfm/ft screen in the upper, low permeability zone, and 3.64×10^{-4} cfm/ft of screen to 4.56 cfm/ft of screen in the lower, high permeability zone. Wellhead flowrates ranged from 60 to 80 cfm. Calculations for the subsurface vapor flowrates based on PET data are provided in Appendix E.

VOC EXTRACTION RATES

Vapor samples for analysis were withdrawn from a sample port in the exhaust stream prior to the emission control device with a pre-cleaned gas tight syringe. All EPA Method 8010 analyses were performed with PID/Hall detectors in series on parallel 60 to 100 meter columns. This configuration gives required separation and dual-detector confirmation. In addition, a second analysis is done on all samples using a second column with a Flame Ionization Detector (FID).

The results of vapor sampling by syringe and GC analysis indicate removal rates in the shallow zone ranging from a non-detect level at Area A to 0.0183 lb/day at Area B. Removal rates in the deep zone range from 0.0174 lb/day at Area A to 11.4 lb/day at Area C. Emission rate calculations can be found in Appendix F.

During the course of each PET, if immediate response was indicated at corresponding monitoring probes, only one vapor sample was withdrawn. If immediate response was not obtained, vapor samples were taken at approximately 30 minute intervals to show the change in concentration over time. The soil gas results show an increase in concentration over time in the shallow zone. This is due to the relatively tight soils at this depth not allowing rapid vapor movement towards the extraction well.

To try and predict how vapor concentrations will decrease with time, each emission rate calculation was calculated from 1 to 90 days. The model results show a considerable reduction in removal rate over time as can be seen on the emission rate calculation sheets. This is to be expected since soil gas is the vapor halo existing around the contamination and should be relatively easy to remove by vacuum methods. It should also be noted that soil concentrations include not only the vapor halo but also interstitial liquid contamination that is either dissolved in the moisture in the soil or exists as a two-phase liquid with the moisture. The continued operation of a SVE system eventually dries the soils, also leading to a rapid reduction in vapor concentration.

PNEUMATIC PERMEABILITY

One critical factor used to determine the feasibility of SVE is the vapor flow rate that can be induced at a particular site. The flow rate is directly dependent upon the air permeability (along

with the applied vacuum). Air permeability describes how easily vapors flow through the soil. Since the air flow rate and the air permeability are line dependent, a higher air permeability will result in a higher flow rate at the same applied vacuum.

Pressure decline data versus time were plotted for each PET. The slope of the pressure decline for each monitoring point was used to estimate the soil permeability to vapor flow by the method discussed in Johnson et al. (1990).

Calculated air permeabilities indicate that SVE is feasible at the MPA. The unusually high permeabilities calculated from the deep monitoring probes were due to the immediate vacuum response at that monitoring point, with little or no change in vacuum pressure over time. A wide range of permeabilities was exhibited in Areas A and C. Possible explanations for these variations could be the heterogeneity of the subsurface and underground utilities creating preferential pathways for air flow.

Air permeabilities obtained during the MPA PETs are included in Appendix G, and summarized in Table 3-5.

TABLE 3-5 AIR PERMEABILITY			
Monitoring Point I.D.	Deep/Shallow	Permeability (cm ²)	Permeability (Darcy)
3A	Deep	7.4×10^{-8}	7.5
5A	Deep	5.7×10^{20}	5.8×10^{28}
7A	Deep	2.0×10^{-13}	2.0×10^{-5}
4A	Shallow	1.6×10^{-13}	1.6×10^{-5}
6A	Shallow	3.4×10^{-14}	3.4×10^{-6}
8A	Shallow	5.5×10^{-13}	5.6×10^{-5}
3B	Deep	1.1×10^{-7}	11.4
5B	Deep	2.5×10^{-10}	0.03
7B	Deep	5.2×10^{-13}	5.2×10^{-5}
4B	Shallow	4.9×10^{-13}	5.0×10^{-5}
6B	Shallow	2.4×10^{-14}	2.4×10^{-6}
8B	Shallow	5.2×10^{-12}	5.2×10^{-4}
3C	Deep	7.2×10^5	7.3×10^{13}
5C	Deep	8.6×10^7	8.7×10^{15}
7C	Deep	3.1	3.1×10^8
4C	Shallow	2.5×10^{-10}	0.03
6C	Shallow	6.7×10^{-6}	684
8C	Shallow	6.5×10^{-13}	6.5×10^{-5}

RADIUS OF INFLUENCE

The application of a vacuum to a well will cause a pressure gradient (a negative pressure) to propagate throughout the zone in proximity to the extraction well. This zone extends radially away from the extraction well for some distance, this distance is known as the radius of influence. Many factors affect the radius of influence. These include the strength of the applied vacuum and soil properties such as porosity and permeability, site features such as stratigraphy and the presence of an impermeable surface barriers within the subsurface. Pressure gradients are greatest near the extraction well and least at a distance from the extraction well.

Subsurface vacuums typically decrease exponentially with distance. The subsurface vacuum data can be displayed graphically by plotting the log of the vacuum versus distance. This graphical technique will linearize the data producing a "best fit" line that represents the theoretical vacuum at a specific distance. By selecting a minimum effective subsurface vacuum level (a vacuum level sufficient to induce flow, typically 0.1 % of the wellhead vacuum) an effective radius of influence (EROI) can be determined.

Subsurface vacuum levels increased steadily during PETs performed on shallow SVE extraction wells. This was expected due to the low permeability soils in which the wells were screened. PETs performed on deep SVE extraction wells showed almost immediate response at corresponding monitoring probes. A series of graphs plotting subsurface vacuum level versus distance during each PET were completed and included in Appendix H. These plots illustrate the propagation of subsurface vacuum with time. An effective radius of influence (EROI) was calculated for each PET based on an effective vacuum level equal to 0.1 % of the applied vacuum at the wellhead. The effective vacuum level of 0.1 % of the applied vacuum resulted in effective vacuum levels ranging from 0.041 to 0.054 inches of water. From the KES report it can be seen that monitoring point vacuum pressures less than the effective vacuum level induced subsurface vapor flow.

Shallow SVE extraction well EROIs ranged from 4 feet (Area B) to 200 feet (Area A). The 4 foot EROI is an abnormal radius in Area B due to an underground utility trench in close proximity to the SVE extraction well possibly causing a short-circuit effect. The 200 foot EROI is also an abnormal radius in Area A, due to vacuum pressures increasing with increasing distance from the extraction well. Deep SVE extraction well EROIs ranged from 54 feet (Area A) to 179 feet (Area C). The 54 foot radius is somewhat smaller than EROIs in other areas,

and can possibly be attributed to the moisture in the soils restricting air flow. Area C is partially covered by concrete sidewalks and a driveway, and has many underground utility lines running through it.

Based on results of the EROI calculations, and taking into consideration surface and subsurface features, a range of EROIs for each area is shown in Table 3-6.

TABLE 3-6 EFFECTIVE RADIUS OF INFLUENCE		
Area, Depth	EROI (ft)	Effective Vacuum Level (in. water)
A, Shallow	15 - 25	0.047
A, Deep	55 - 65	0.047
B, Shallow	15 - 20	0.054
B, Deep	100 - 120	0.041
C, Shallow	30 - 50	0.054
C, Deep	50 - 100	0.041

3.1.3 Comparison to Test Objectives

The first objective was to confirm the status of TCE contaminated soils as described in the RI/FS. Soil sampling analysis during MPA drilling activities indicated a decline in TCE contamination in soils. This was most likely due to percolation of rain water through the soil, and resulting vertical migration of TCE towards the saturated zone. Decline in concentration is most evident in Area A, as this area has no surface seal.

The second objective was to obtain soil/air permeability and pressure thresholds. These objectives were obtained during the MPA study and were discussed earlier in this report.

The third objective was to obtain data necessary to evaluate air emission controls during full scale SVE operation. Based on soil vapor analysis and the maximum amount of TCE allowed to be discharged to the atmosphere (3 lbs/hr, 15 lbs/day, 10 tons/year), emission control devices will be necessary once additional SVE extraction wells are in place.

The final objective was to determine site specific design criteria for a full scale SVE system, particularly SVE extraction well spacing. Additional information is needed before detailed system design, namely, actual number of SVE extraction wells.

Treatability study data indicate that deep soil contamination did not exceed the 533 $\mu\text{g/kg}$ cleanup criteria. Additional SVE well drilling will still be based on the spacing pattern outlined in the RD/RA Workplan, with emphasis placed on shallow soil extraction well spacings and delineation of shallow soil contamination.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on results of MPA drilling activities and PETs, the SVE field design will proceed as follows:

- At Areas B and C, install borings (to about 5 ft. above the top of the Jackson Clay, or about 50 ft. deep) at 150 ft. centers on a triangular pattern.
- At Area A begin a triangular pattern of borings spaced at 75 ft. beginning to the south of CCSVE1A.

Soil samples will be taken and analyzed by the Woodson-Tenent screening method at 10 ft. intervals beginning at 5 ft. below grade.

This pattern of widely spaced borings may not sufficiently delineate current shallow soil contamination. Additional borings, limited to the shallow zone will be required at approximately 60 ft. spacings at all areas. Once the shallow zone area has been delineated, a decision can be made regarding the most efficient shallow zone extraction approach— horizontal galleries or vertical extraction wells. As the pattern of contamination, both deep and shallow becomes evident, field engineering decisions regarding well number and spacing patterns may be required to assure practical system design.

REFERENCES

- USEPA. (1992). *Guide for Conducting Treatability Studies under CERCLA*. (EPA/540/R-92/071a). Washington, DC. Office of Solid Waste and Emergency Response.
- USEPA. (1991). *Guide for Conducting Treatability Studies under CERCLA: Soil Vapor Extraction. Interim Guidance*. (EPA/540/2-91/019A). Washington, DC. Office of Emergency and Remedial Response.
- P.C. Johnson, et. al. (1990). *A Practical Approach to the Design, Operation, and Monitoring of In-Situ Soil Venting Systems*. Houston, TX. Westhollow Research Center.
- EnSafe. (1992). *Collierville Site, Feasibility Study*. Memphis, Tennessee.
- EnSafe. (1991). *Collierville Site, Remedial Investigation Report*. Memphis, Tennessee.

APPENDIX A

SHELBY TUBE SAMPLE ANALYTICAL REPORTS



Tri-State Testing Services, Inc.

Measurement of Hydraulic Conductivity

Client: EnSafe

Date of Report: 12/01/93

Project No.: E-2-467

Project Name: Carrier Corp. 97 S. Byhalia Road Collierville, TN

Sample I.D.: CCMP B - 3, Shelby tube # 1, Depth 13.0' - 15.0'

Soil Description: Tan Clayey Silt

	<u>Pre-Test</u>	<u>Post Test</u>
Wet Density (Lbs/ft ³)	113.7	131.4
Dry Density (Lbs/ft ³)	99.7	110.0
Moisture (% Dry Wt)	14.0	19.5

Permeability

Temperature Correction, $R_t = 1.056$

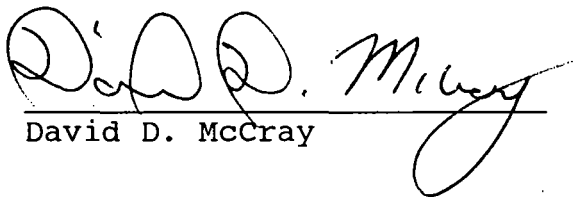
$$\begin{aligned}K_1 &= 5.1 \times 10^{-7} \text{ cm/sec} \\K_2 &= 4.9 \times 10^{-7} \text{ cm/sec} \\K_3 &= 2.7 \times 10^{-7} \text{ cm/sec} \\K_4 &= 3.5 \times 10^{-7} \text{ cm/sec}\end{aligned}$$

Coefficient of Permeability, $K_{20} = 3.6 \times 10^{-7} \text{ cm/sec}$

Tested in accordance with Method 9100 of Test Methods for evaluation Solid Waste, Third Addition (SW-846) and in general accordance with ASTM D-5084-90.

Lab No. L-93-1064A

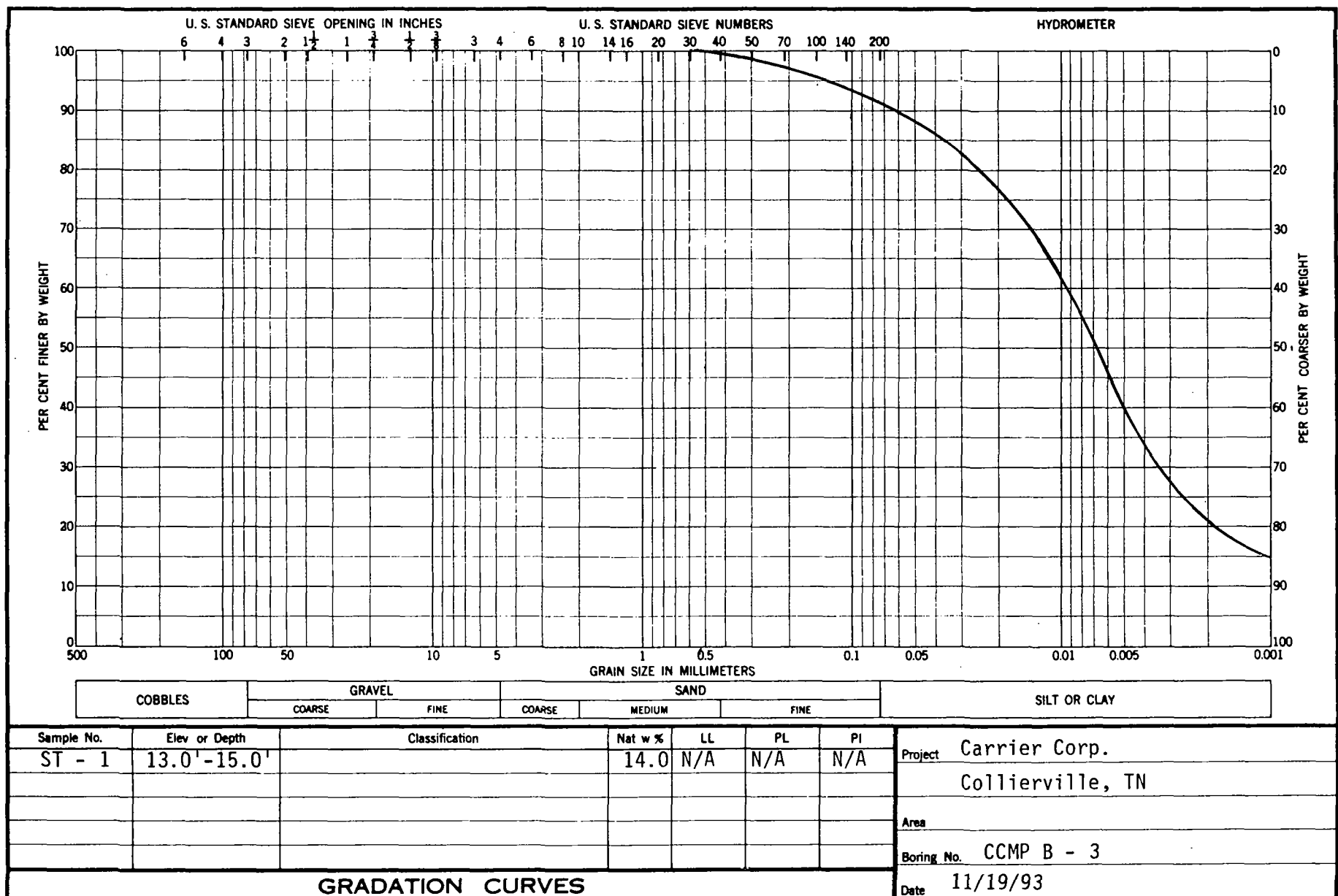
Reviewed By:


David D. McCray



6756 Buckles Cove • Memphis, TN 38133
(901) 385-1199 • Fax (901) 386-6614







Tri-State Testing Services, Inc.

Measurement of Hydraulic Conductivity

Client: EnSafe

Date of Report: 12/01/93

Project No.: E-2-467

Project Name: Carrier Corp. 97 S. Byhalia Road Collierville, TN

Sample I.D.: CCMP B - 3, Shelby tube # 2, Depth 32.0' - 33.0'

Soil Description: Yellow Sand

	<u>Pre-Test</u>	<u>Post Test</u>
Wet Density (Lbs/ft ³)	126.3	136.4
Dry Density (Lbs/ft ³)	122.0	128.2
Moisture (% Dry Wt)	3.5	6.4

Permeability

Temperature Correction, $R_t = 1.086$

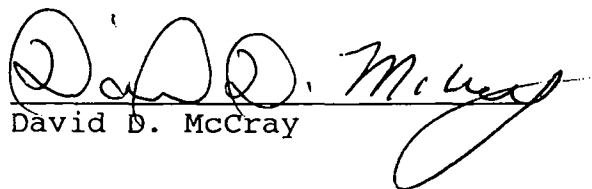
$$\begin{aligned}K_1 &= 1.1 \times 10^{-3} \text{ cm/sec} \\K_2 &= 8.6 \times 10^{-4} \text{ cm/sec} \\K_3 &= 8.0 \times 10^{-4} \text{ cm/sec} \\K_4 &= 1.1 \times 10^{-3} \text{ cm/sec}\end{aligned}$$

Coefficient of Permeability, $K_{20} = 1.1 \times 10^{-3} \text{ cm/sec}$

Tested in accordance with Method 9100 of Test Methods for evaluation Solid Waste, Third Addition (SW-846) and in general accordance with ASTM D-5084-90.

Lab No. L-93-1064B

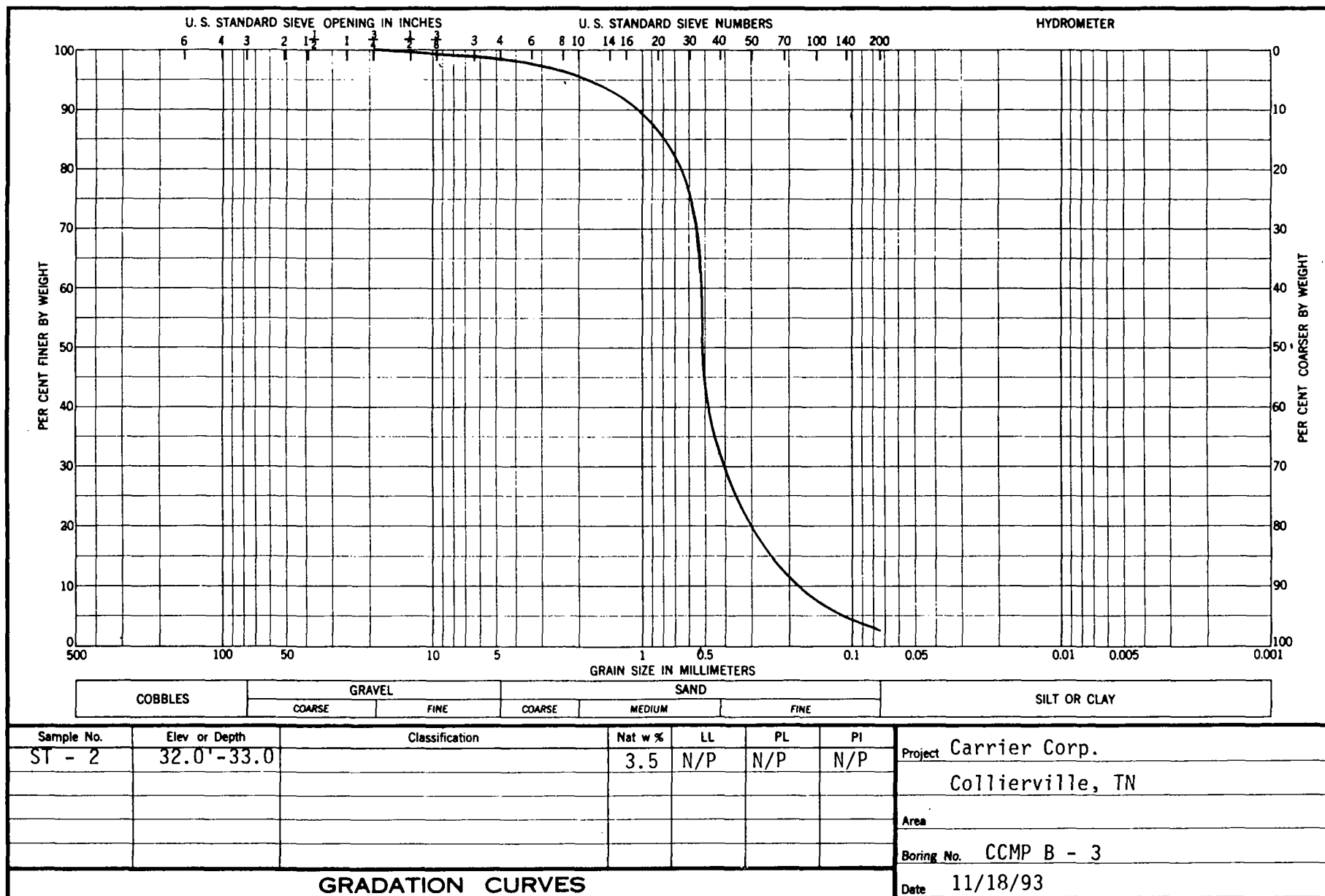
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David D. McCray



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Tri-State Testing Services, Inc.

Measurement of Hydraulic Conductivity

Client: EnSafe

Date of Report: 12/02/93

Project No.: E-2-467

Project Name: Carrier Corp. 97 S. Byhalia Road Collierville, TN

Sample I.D.: C - 8, Shelby tube # 1, Depth 13.0' - 15.0'

Soil Description: Brown Clayey Silt

	<u>Pre-Test</u>	<u>Post Test</u>
Wet Density (Lbs/ft ³)	121.0	130.4
Dry Density (Lbs/ft ³)	101.3	103.2
Moisture (% Dry Wt)	19.5	26.4

Permeability

Temperature Correction, $R_t = 1.056$

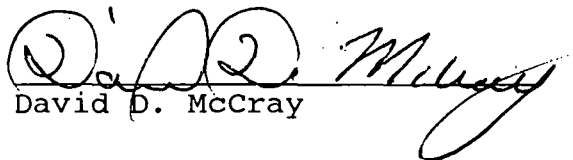
$$\begin{aligned}K_1 &= 4.4 \times 10^{-6} \text{ cm/sec} \\K_2 &= 4.1 \times 10^{-6} \text{ cm/sec} \\K_3 &= 4.6 \times 10^{-6} \text{ cm/sec} \\K_4 &= 4.1 \times 10^{-6} \text{ cm/sec}\end{aligned}$$

Coefficient of Permeability, $K_{20} = 4.5 \times 10^{-6} \text{ cm/sec}$

Tested in accordance with Method 9100 of Test Methods for evaluation Solid Waste, Third Addition (SW-846) and in general accordance with ASTM D-5084-90.

Lab No. L-93-1064C

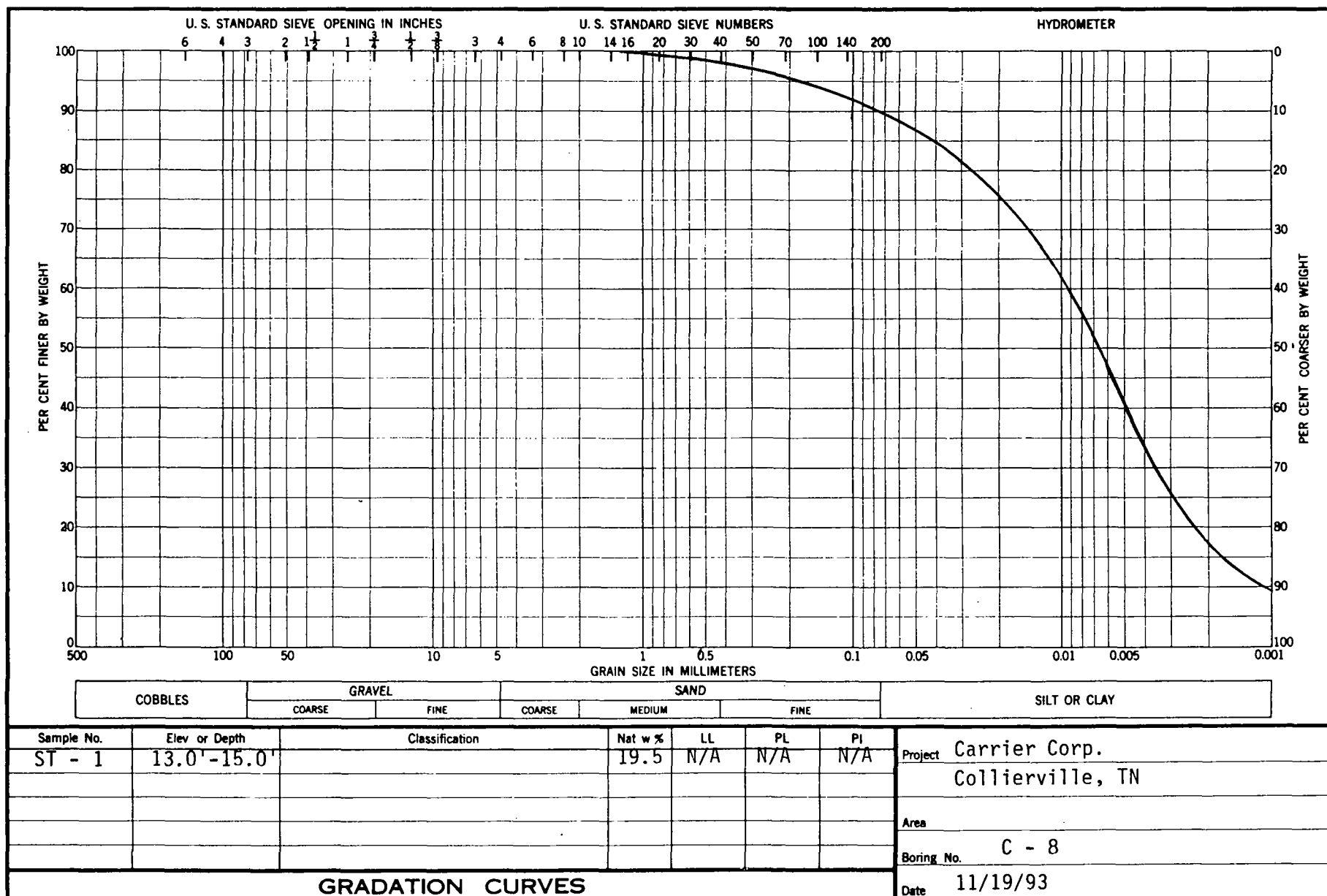
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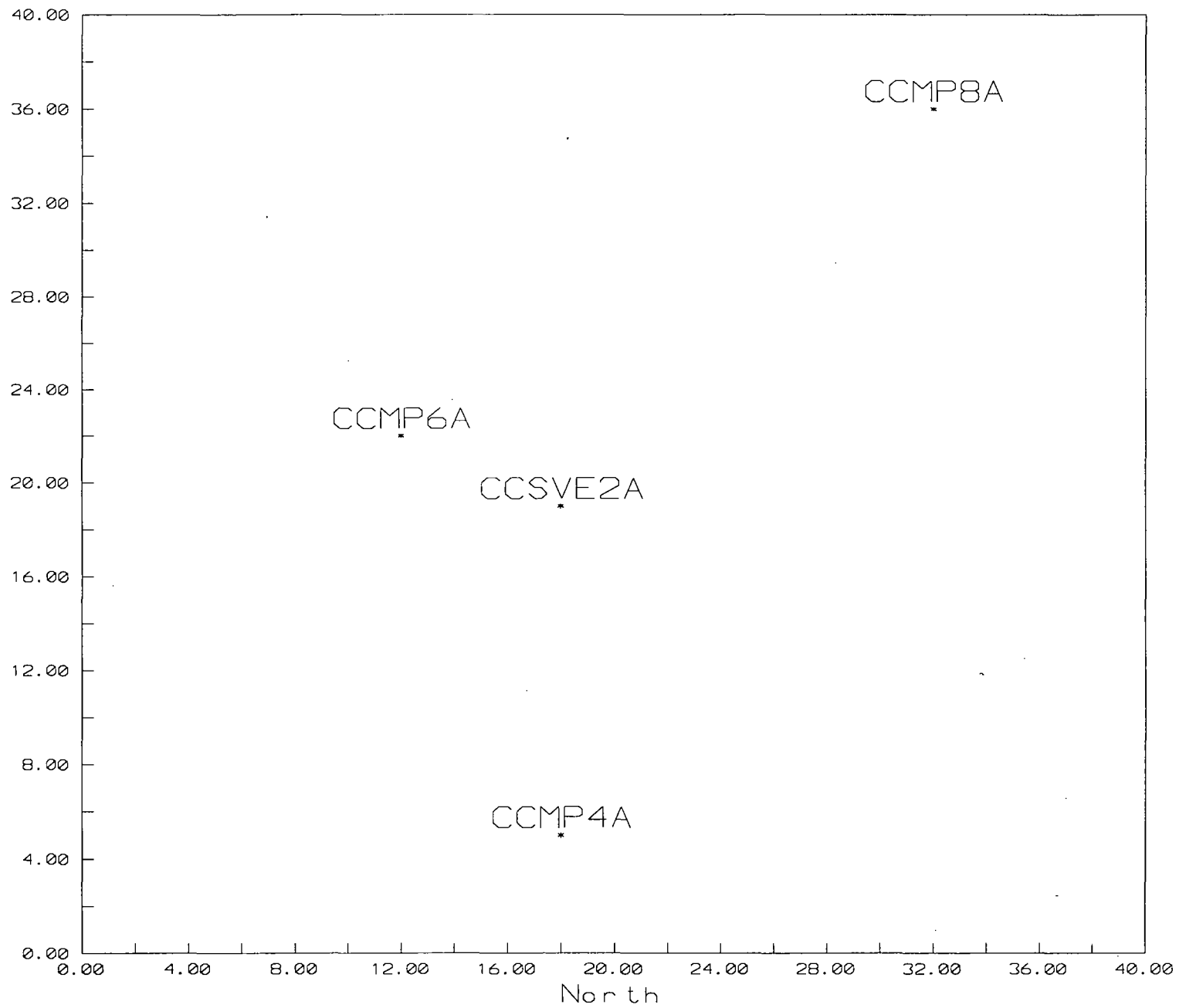




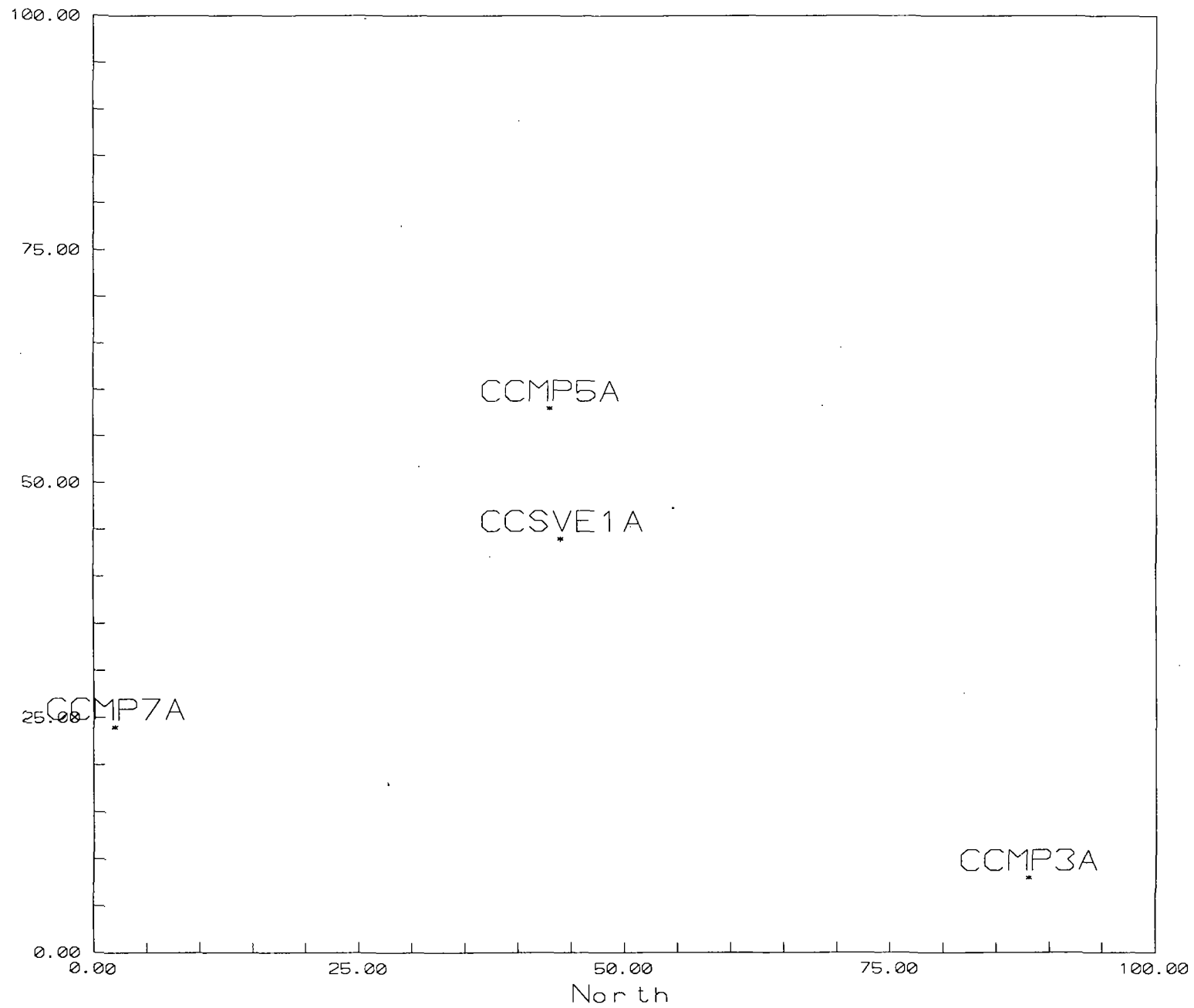
APPENDIX B

SVE WELL/MONITORING POINT LAYOUT

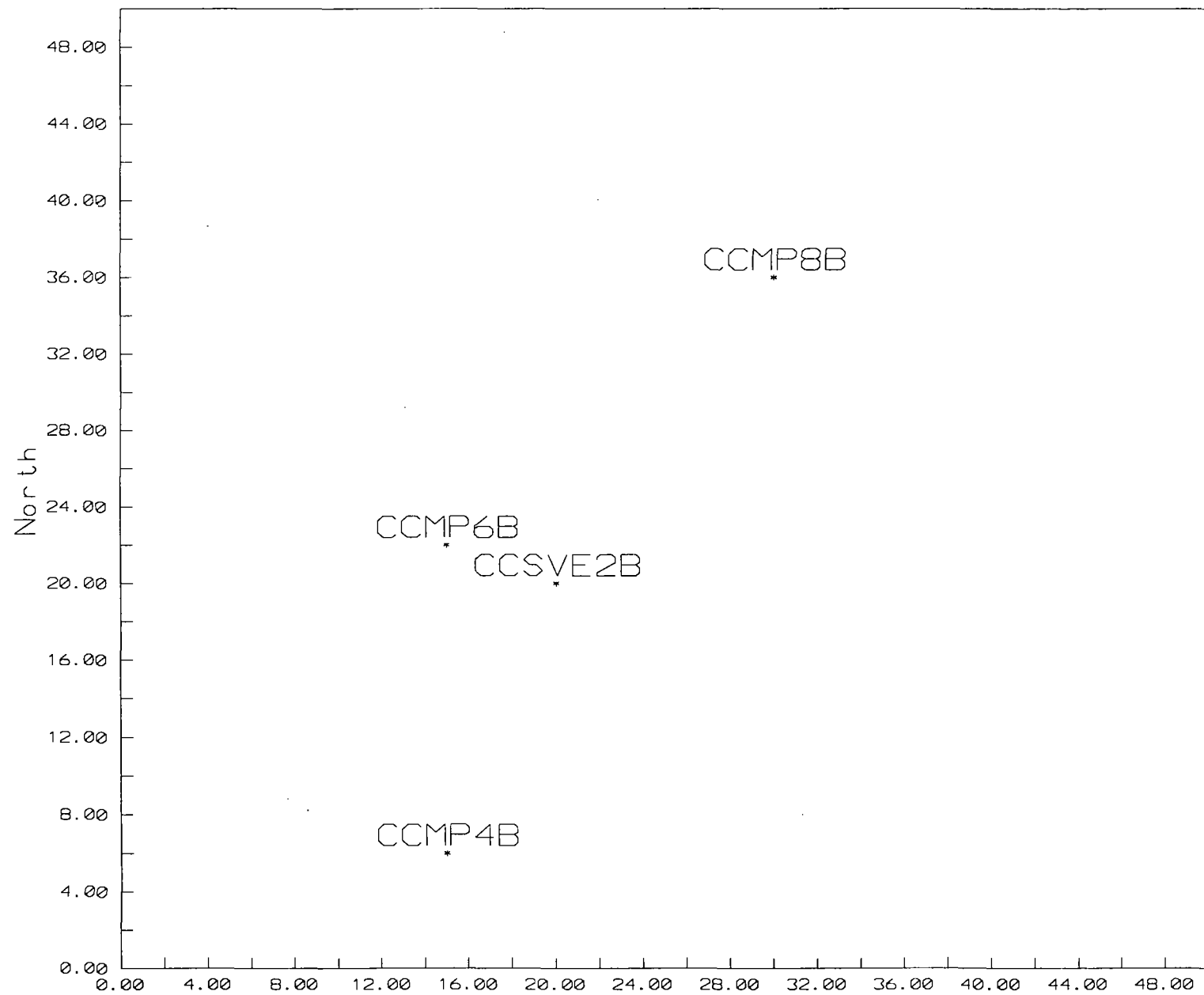
Area A, Shallow Zone



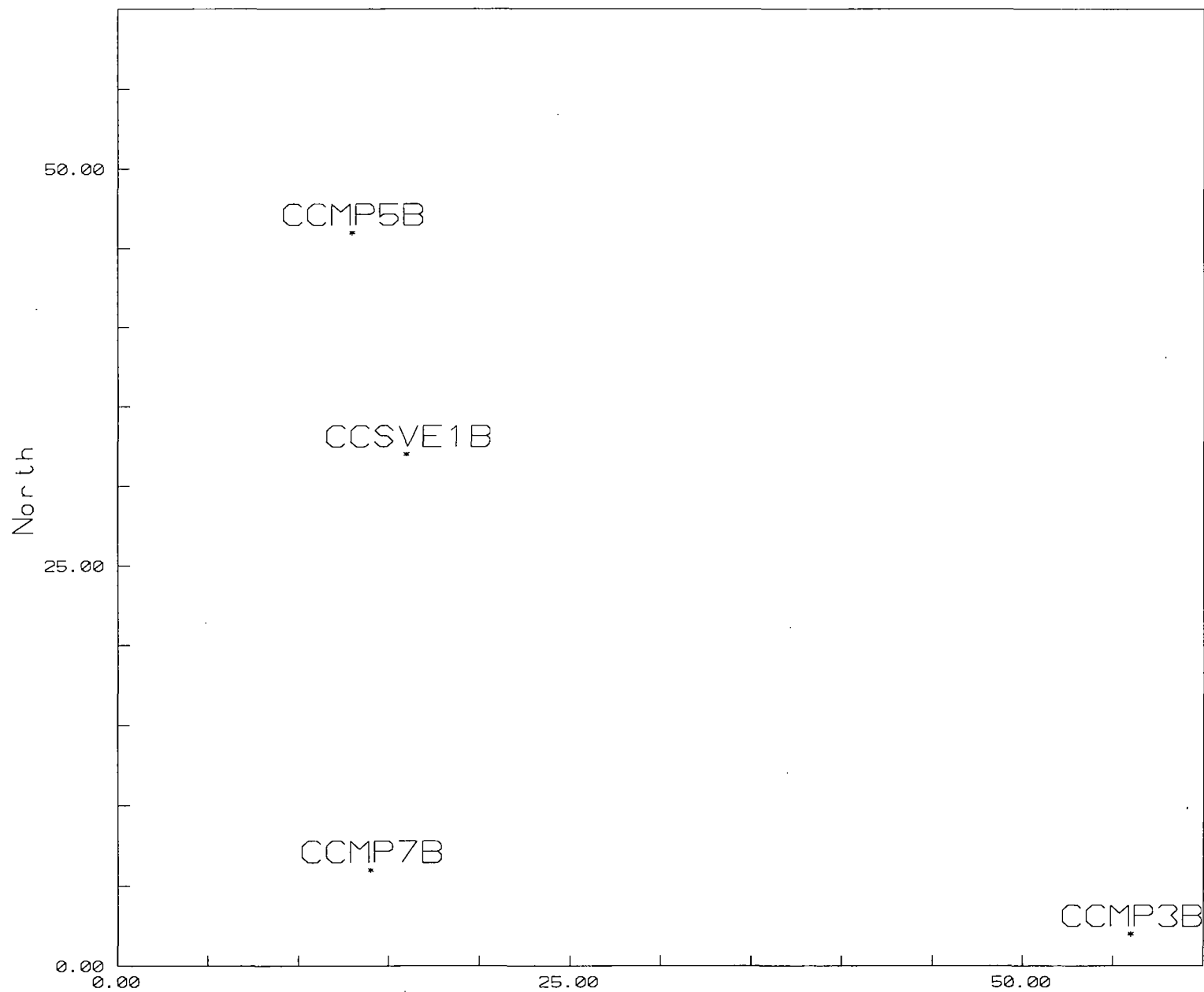
Area A, Deep Zone



Area B, Shallow Zone

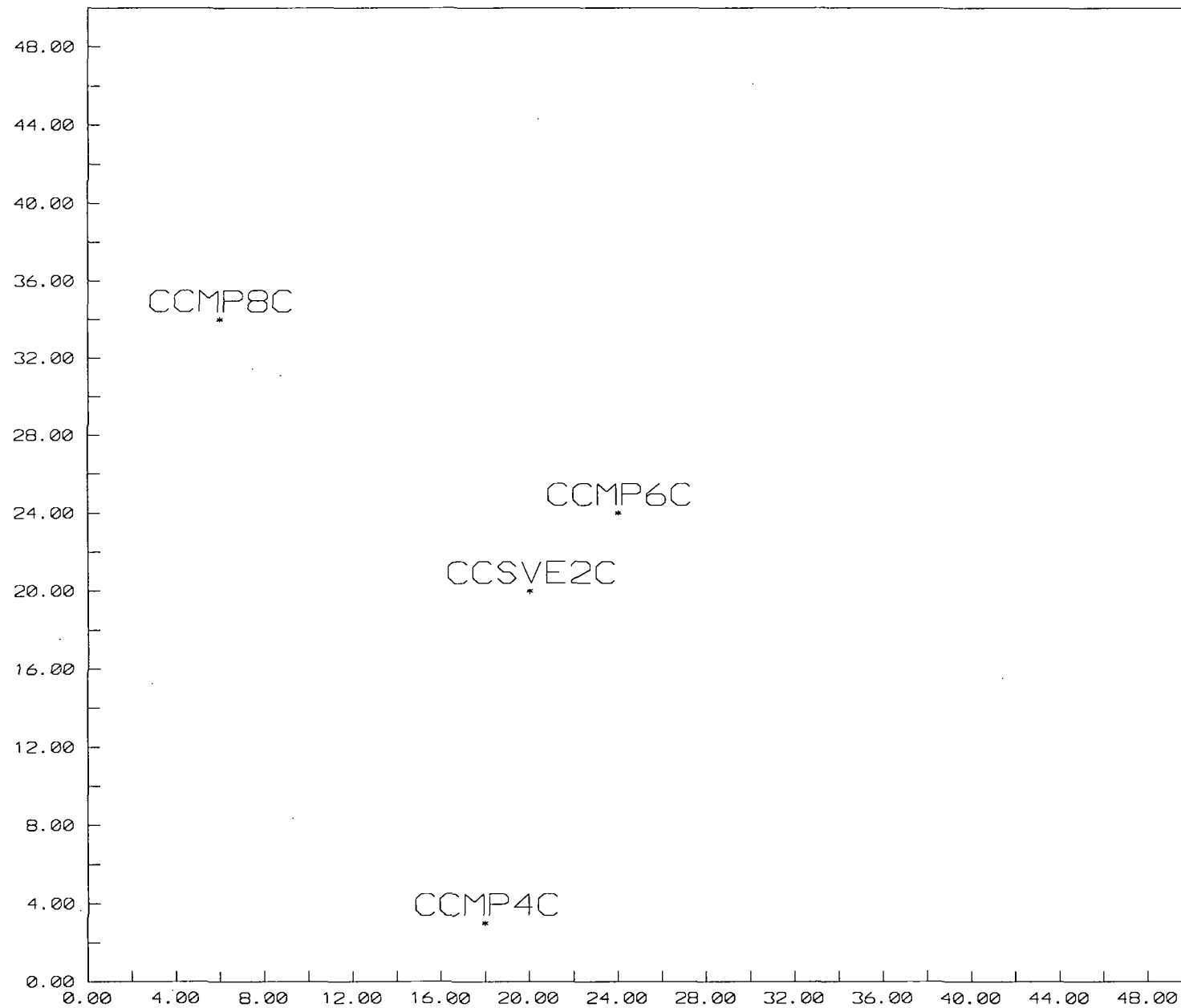


Area B, Deep Zone



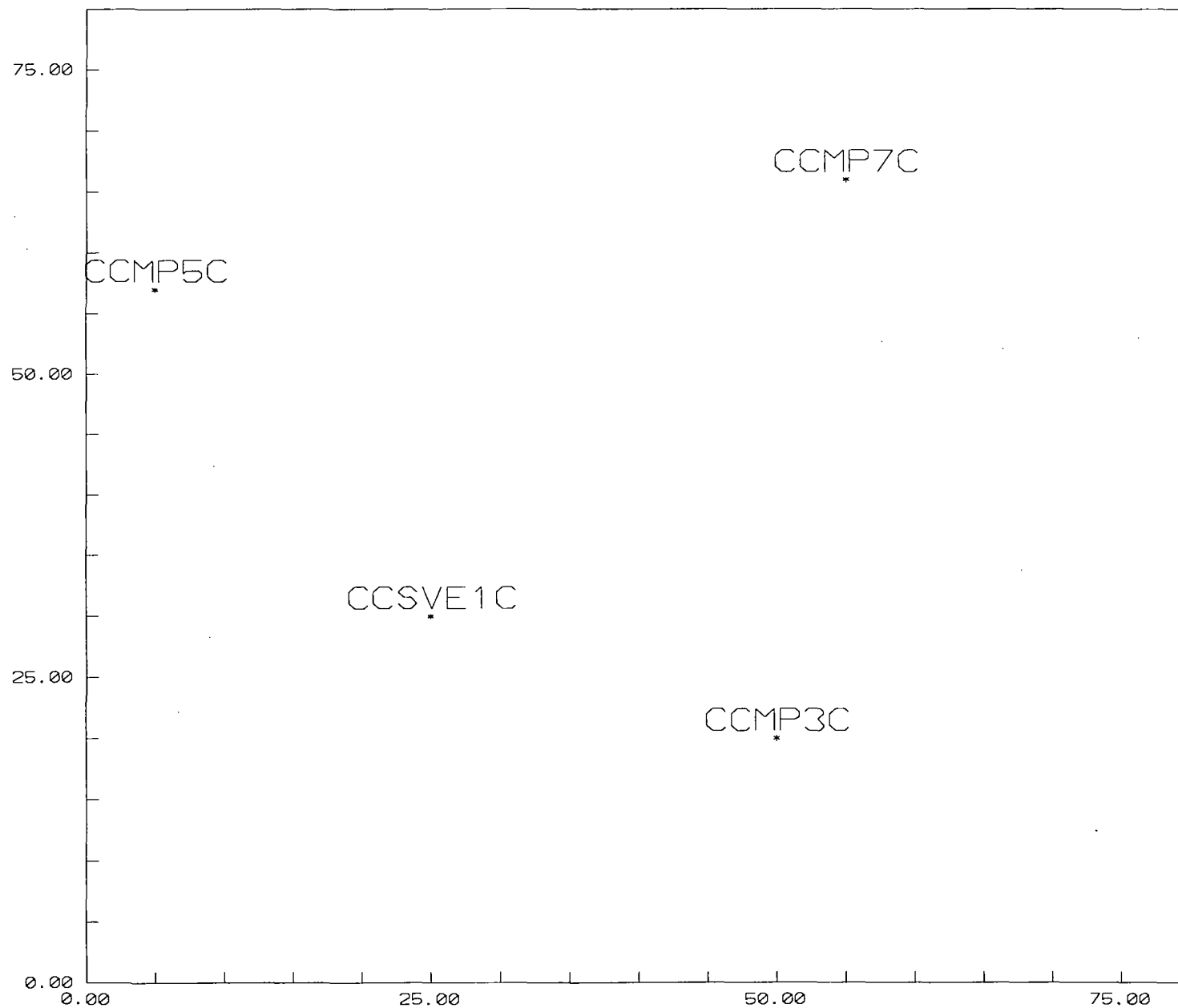
Area C, Shallow Zone

North



Area C, Deep Zone

North



APPENDIX C

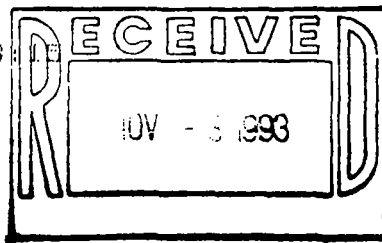
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W-T SAMPLE NO.: M93-330517
SAMPLE OF: SOIL
SAMPLE ID: CC SVE-1A-S1 11-2-93 8:15
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/04/93
W-T ENTRY DATE: 11/03/93



ENSAFÉ
* ATTN CRAIG WISE
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	118	PPB	

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SAMPLE OF: SOIL
SAMPLE ID: CC SVE-1A-S2 11-2-93 8:41
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/04/93
W-T ENTRY DATE: 11/03/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	72	PPB	

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W-T SAMPLE NO.: M93-330519
SAMPLE OF: SOIL
SAMPLE ID: CC SVE-1A-S3 11-2-93 9:00
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/04/93
W-T ENTRY DATE: 11/03/93

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* ATTN CRAIG WISE
PO BOX 341315
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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	13	PPB	

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W-T SAMPLE NO.: M93-330520
SAMPLE OF: SOIL
SAMPLE ID: CC SVE-2A-S1 11-2-93 13:10
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/04/93
W-T ENTRY DATE: 11/03/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	53	PPB	

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SAMPLE OF: SOIL
SAMPLE ID: CC SVE-2A-S2 11-2-93 13:20
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/04/93
W-T ENTRY DATE: 11/03/93

ENSAFE
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PO BOX 341315
MEMPHIS

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R E P O R T O F A N A L Y S I S

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TRICHLOROETHYLENE	26	PPB	

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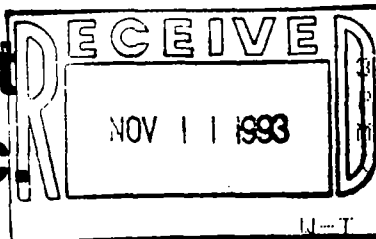
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W-T SAMPLE NO.: M93-330816
SAMPLE OF: SOIL
SAMPLE ID: CCMP-3A-S1
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/08/93
W-T ENTRY DATE: 11/05/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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W-T SAMPLE NO.: M93-330817
SAMPLE OF: SOIL
SAMPLE ID: CCMP-3A-S2
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/08/93
W-T ENTRY DATE: 11/05/93

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TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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W-T SAMPLE NO.: M93-330818
SAMPLE OF: SOIL
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PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/08/93
W-T ENTRY DATE: 11/05/93

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TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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W-T SAMPLE NO.: M93-330819
SAMPLE OF: SOIL
SAMPLE ID: CCMP-7A-S2
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/08/93
W-T ENTRY DATE: 11/05/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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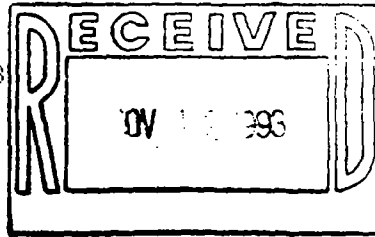
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W-T SAMPLE NO.: M93-331081
SAMPLE OF: SOIL
SAMPLE ID: CCSVE1B-S1 11-5-93
PO NUMBER:
CUST #: 01314500



W-T REPORTING DATE: 11/11/93
W-T ENTRY DATE: 11/09/93

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PO BOX 341315
MEMPHIS

TN 38184

REPORT OF ANALYSIS
CORRECTED REPORT
SUPERSEDES REPORT DATED 11/10/93
ORIGINAL CORRECTED
RESULT RESULT UNITS

LAB CODE #

TEST

TRICHLOROETHYLENE

2,740 548 PPB

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W-T SAMPLE NO.: M93-331082
SAMPLE OF: SOIL
SAMPLE ID: CCSVE1B-S2 11-5-93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/11/93
W-T ENTRY DATE: 11/09/93

ENSAFE
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PO BOX 341315
MEMPHIS

TN 38184

REPORT OF ANALYSIS CORRECTED REPORT

SUPERSEDES REPORT DATED 11/10/93
ORIGINAL CORRECTED

TEST	RESULT	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	130	26	PPB	

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W-T SAMPLE NO.: M93-331083
SAMPLE OF: SOIL
SAMPLE ID: CCSVE1B-S3 11-5-93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/11/93
W-T ENTRY DATE: 11/09/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

REPORT OF ANALYSIS CORRECTED REPORT

SUPERSEDES REPORT DATED 11/10/93

ORIGINAL CORRECTED

TEST	RESULT	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	190	38	PPB	

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P O BOX 2105
MEMPHIS TN 38101
(901)525-6333

W-T SAMPLE NO.: M93-331084
SAMPLE OF: SOIL
SAMPLE ID: CCSVE1B-S4 11-5-93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/11/93
W-T ENTRY DATE: 11/09/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S CORRECTED REPORT

SUPERSEDES REPORT DATED 11/10/93

ORIGINAL CORRECTED

TEST	RESULT	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	38	10	PPB	

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MEMPHIS TN 38101
(901)525-6333

W-T SAMPLE NO.: M93-331085
SAMPLE OF: SOIL
SAMPLE ID: CCSVE1B-S5 11-5-93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/11/93
W-T ENTRY DATE: 11/09/93

ENSAFE
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TN 38184

REPORT OF ANALYSIS CORRECTED REPORT

SUPERSEDES REPORT DATED 11/10/93

ORIGINAL CORRECTED

TEST	RESULT	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	190	38	PPB	

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W-T SAMPLE NO.: M93-331086
SAMPLE OF: SOIL
SAMPLE ID: CCSVE1B-26 11-5-93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/11/93
W-T ENTRY DATE: 11/09/93

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R E P O R T O F A N A L Y S I S CORRECTED REPORT

SUPERSEDES REPORT DATED 11/10/93

ORIGINAL CORRECTED

TEST	RESULT	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	200	40	PPB	

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W-T SAMPLE NO.: M93-331087
SAMPLE OF: SOIL
SAMPLE ID: CCSVE2B-S1 11-5-93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/11/93
W-T ENTRY DATE: 11/09/93

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REPORT OF ANALYSIS CORRECTED REPORT

SUPERSEDES REPORT DATED 11/10/93
ORIGINAL CORRECTED

TEST	RESULT	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	8,000	1,600	PPB	

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W-T SAMPLE NO.: M93-331088
SAMPLE OF: SOIL
SAMPLE ID: CCSVE2B-S2 11-5-93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/11/93
W-T ENTRY DATE: 11/09/93

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R E P O R T O F A N A L Y S I S CORRECTED REPORT

SUPERSEDES REPORT DATED 11/10/93

ORIGINAL CORRECTED

TEST

RESULT RESULT UNITS

LAB CODE #

TRICHLOROETHYLENE

12,000 2,400 PPB

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W-T SAMPLE NO.: M93-331089
SAMPLE OF: SOIL
SAMPLE ID: CCSVE2B-S3 11-5-93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/10/93
W-T ENTRY DATE: 11/09/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	650	PPB	

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W-T SAMPLE NO.: M93-331429
SAMPLE OF: SOIL
SAMPLE ID: CCMP-3B-S1 11/9/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	42	PPB	

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W-T SAMPLE NO.: M93-331430
SAMPLE OF: SOIL
SAMPLE ID: CCMP-38-S2 11/9/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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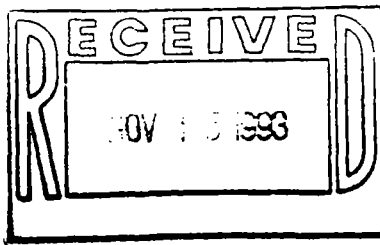
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W-T SAMPLE NO.: M93-331427
SAMPLE OF: SOIL
SAMPLE ID: CCMP-6B-S1 11/9/93
PO NUMBER:
CUST #: 01314500



W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	850	PPB	

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W-T SAMPLE NO.: M93-331428
SAMPLE OF: SOIL
SAMPLE ID: CCMP-6B-S2 11/9/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	360	PPB	

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W-T SAMPLE NO.: M93-331433
SAMPLE OF: SOIL
SAMPLE ID: CCMP-7B-1S 11/10/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	250	PPB	

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W-T SAMPLE NO.: M93-331434
SAMPLE OF: SOIL
SAMPLE ID: CCMP-7B-2S 11/10/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	35	PPB	

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W-T SAMPLE NO.: M93-331436
SAMPLE OF: SOIL
SAMPLE ID: CCMP-7B-3S 11/10/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	19	PPB	

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W-T SAMPLE NO.: M93-331435
SAMPLE OF: SOIL
SAMPLE ID: CCMP-8B-1S 11/10/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	60	PPB	

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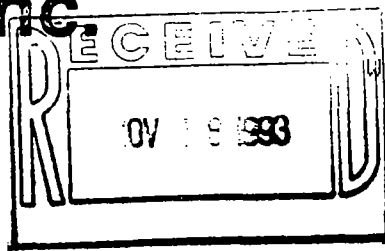
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W-T SAMPLE NO.: M93-331641
SAMPLE OF: SOIL
SAMPLE ID: CCSVE-1C-1S 11/11/93
PO NUMBER:
CUST #: 01314500



W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	80	PPB	

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W-T SAMPLE NO.: M93-331642
SAMPLE OF: SOIL
SAMPLE ID: CCSVE-1C-2S 11/11/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	72	PPB	

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W-T SAMPLE NO.: M93-331643
SAMPLE OF: SOIL
SAMPLE ID: CCSVE-1C-3S 11/11/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	51	PPB	

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W-T SAMPLE NO.: M93-331644
SAMPLE OF: SOIL
SAMPLE ID: CCSVE-1C-4S 11/11/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	34	PPB	

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W-T SAMPLE NO.: M93-331645
SAMPLE OF: SOIL
SAMPLE ID: CCSVE-1C-5S 11/11/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	12	PPB	

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W-T SAMPLE NO.: M93-331647
SAMPLE OF: SOIL
SAMPLE ID: CCSVE-2C-1S 11/11/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	116	PPB	

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W-T SAMPLE NO.: M93-331648
SAMPLE OF: SOIL
SAMPLE ID: CCSVE-2C-2S 11/11/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	63	PPB	

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W-T SAMPLE NO.: M93-331649
SAMPLE OF: SOIL
SAMPLE ID: CCSVE-2C-35 11/11/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

REPRINT DATE: 11/16/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	29	PPB	

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W-T SAMPLE NO.: M93-332061
SAMPLE OF: SOIL
SAMPLE ID: CCMP-3C-S1 11/16/93 1000
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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W-T SAMPLE NO.: M93-332062
SAMPLE OF: SOIL
SAMPLE ID: CCMP-3C-S2 11/16/93 1015
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

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REPORT OF ANALYSIS

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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W-T SAMPLE NO.: M93-331650
SAMPLE OF: SOIL
SAMPLE ID: CCMP-4C-1S 11/12/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	102	PPB	

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W-T SAMPLE NO.: M93-331646
SAMPLE OF: SOIL
SAMPLE ID: CCSMP-6C-1S 11/12/93
PO NUMBER:
CUST #: 01314500

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W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	70	PPB	

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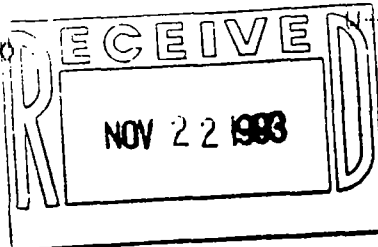


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W-T SAMPLE NO.: M93-332059
SAMPLE OF: SOIL
SAMPLE ID: CCMP-7C-S1 11/15/93 1430
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93



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REPORT OF ANALYSIS

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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W-T SAMPLE NO.: M93-332060
SAMPLE OF: SOIL
SAMPLE ID: CCMP-7C-S2 11/15/93 1450
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	12	PPB	

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W-T SAMPLE NO.: M93-332063
SAMPLE OF: SOIL
SAMPLE ID: CCMP-8C-S1 11/16/93 1250
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	317	PPB	

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W-T SAMPLE NO.: M93-332068
SAMPLE OF: CEMENT
SAMPLE ID: CCFB-CEMENT 11/16/93 940
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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W-T SAMPLE NO.: M93-332067
SAMPLE OF: BENTONITE
SAMPLE ID: CCFB-BENTONITE 11/16/93 900
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

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R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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W-T SAMPLE NO.: M93-332066
SAMPLE OF: WATER
SAMPLE ID: CCRB-C 11/16/93 850
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

RESPECTFULLY SUBMITTED,
WOODSON-TENENT LABORATORIES, INC.

LARS REIMANN
BRANCH MANAGER



Analytical and Consulting Chemists Since 1933



Woodson-Tenent Laboratories, Inc.

345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)525-6333

W-T SAMPLE NO.: M93-332065
SAMPLE OF: SOIL
SAMPLE ID: CCFB-SAND 11/16/93 .1400
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

RESPECTFULLY SUBMITTED,
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345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)525-6333

W-T SAMPLE NO.: M93-332064
SAMPLE OF: WATER
SAMPLE ID: CCFB-2 1 11/15/93 1600
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/19/93
W-T ENTRY DATE: 11/17/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

RESPECTFULLY SUBMITTED,
WOODSON-TENENT LABORATORIES, INC.

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345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)525-6333

W-T SAMPLE NO.: M93-331651
SAMPLE OF: WATER
SAMPLE ID: CCRB-B 11/10/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/16/93
W-T ENTRY DATE: 11/15/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

RESPECTFULLY SUBMITTED,
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Woodson-Tenent Laboratories, Inc.

345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)525-6333

W-T SAMPLE NO.: M93-330820
SAMPLE OF: WATER
SAMPLE ID: CCRB-A
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/08/93
W-T ENTRY DATE: 11/05/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

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Woodson-Tenent Laboratories, Inc.

345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)525-6333

W-T SAMPLE NO.: M93-331431
SAMPLE OF: SOIL
SAMPLE ID: CCSOP-1 11/9/93
PO NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	250	PPB	

RESPECTFULLY SUBMITTED,
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345 ADAMS AVE
P O BOX 2135
MEMPHIS TN 38101
(901)525-6333

W-T SAMPLE NO.: M93-331432
SAMPLE OF: WATER
SAMPLE ID: CCFB-1 11/9/93
PD NUMBER:
CUST #: 01314500

W-T REPORTING DATE: 11/12/93
W-T ENTRY DATE: 11/10/93

ENSAFE
ATTN PHIL COOP
PO BOX 341315
MEMPHIS

TN 38184

R E P O R T O F A N A L Y S I S

TEST	RESULT	UNITS	LAB CODE #
TRICHLOROETHYLENE	<10	PPB	

RESPECTFULLY SUBMITTED,
WOODSON-TENENT LABORATORIES, INC.

LARS REIMANN
BRANCH MANAGER



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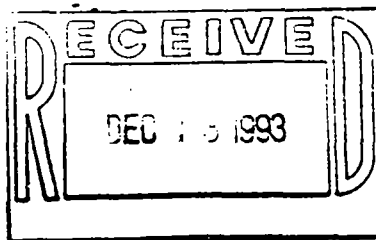


APPENDIX D

TEG ANALYTICAL REPORTS



**TRANSGLOBAL
ENVIRONMENTAL
GEOCHEMISTRY**



Mr. Darrell Richardson
ENSAFE, Inc.
5724 Summer Trees Dr.
Memphis, TN 38134

December 8, 1993

SUBJECT: DATA REPORT - CARRIER CORP. -- COLLIERVILLE, TN
PROJECT # 1048-59 & 1048-59NRS.

TEG PROJECT # 931202G1

Mr. Richardson:

Please find enclosed a data report for soil vapor analyses from the Carrier in Collerville, Tennessee. The samples were analyzed in TEG's California DOHS certified mobile laboratory (Cert. #1890). TEG conducted the following analyses:

-- 16 soil vapor samples for volatile halogenated hydrocarbons by EPA Method 8010.

The results of the analyses are summarized in the attached table. Applicable detection limits and blank results are included.

TEG appreciates the opportunity to provide analytical services to ENSAFE for this project. If you have any questions relating to this data or report, please contact us at (404)919-0805.

Sincerely,

Barton K. Moore
Senior Chemist



ENSAFE
PROJECT # 1048-59
CARRIER PLANT - COLLIERVILLE, TN

TEG PROJECT # 931202G1

VOLATILE HALOGENATED HYDROCARBON ANALYSES OF SOIL VAPOR (EPA METHOD 8010)
DATA IN MICROGRAMS/LITER OF VAPOR (ug/l-vapor)

	BLANK CCSVE1A1 CCSVE1A2 CCSVE1A3 CCSVE2A1 CCSVE2A2 CCSVE1B1						
DATE	12/02/93	12/02/93	12/02/93	12/02/93	12/02/93	12/02/93	12/02/93
ANALYSIS TIME	7:48	8:59	9:29	10:04	11:56	12:24	13:45
FREON 12	ND	ND	ND	ND	ND	ND	ND
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	4.2
FREON 11	ND	ND	ND	ND	ND	ND	ND
1,1 DICHLORO ETHENE	ND	ND	ND	ND	ND	ND	6.3
METHYLENE CHLORIDE	ND	ND	ND	ND	ND	ND	ND
1,2 TR DICHLORO ETHENE	ND	ND	ND	ND	ND	ND	0.6
1,1 DICHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND
1,2 CIS DICHLORO ETHENE	ND	ND	ND	ND	ND	ND	76.8
1,1,1 TRICHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND
1,2 DICHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND
TRICHLORO ETHENE	ND	ND	0.7	2.5	ND	ND	1250
1,2 DICHLORO PROPANE	ND	ND	ND	ND	ND	ND	ND
BROMO DICHLORO METHANE	ND	ND	ND	ND	ND	ND	ND
CIS DICHLORO PROPENE	ND	ND	ND	ND	ND	ND	ND
TRANS DICHLORO PROPENE	ND	ND	ND	ND	ND	ND	ND
1,1,2 TRICHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND
TETRACHLORO ETHENE	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND
TETRACHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND

ND INDICATES NOT DETECTED AT DETECTION LIMIT OF 0.5 UG/L-VAPOR FOR EACH COMPOUND

ANALYSES PERFORMED ON SITE IN TEG'S DOHS CERTIFIED MOBILE LABORATORY (CERT #1890)
ANALYSES PERFORMED BY: BARTON MOORE
DATA REVIEWED BY: BLAYNE HARTMAN



ENSAFÉ
PROJECT # 1048-59
CARRIER PLANT - COLLIERSVILLE, TN

TEG PROJECT # 931202G1

VOLATILE HALOGENATED HYDROCARBON ANALYSES OF SOIL VAPOR (EPA METHOD 8010)
DATA IN MICROGRAMS/LITER OF VAPOR (ug/l-vapor)

	CCSVE2B1	CCSVE2B2	CCSVE2B3	CCSVE2C1	CCSVE2C2	CCSVE1C1	CCSVE1C2
DATE	12/02/93	12/02/93	12/02/93	12/02/93	12/02/93	12/02/93	12/02/93
ANALYSIS TIME	15:07	15:37	16:29	17:26	18:08	18:47	19:17
FREON 12	ND	ND	ND	ND	ND	ND	ND
VINYL CHLORIDE	ND	ND	ND	ND	ND	ND	ND
FREON 11	ND	ND	ND	ND	ND	ND	ND
1,1 DICHLORO ETHENE	ND	ND	ND	ND	ND	ND	ND
METHYLENE CHLORIDE	ND	ND	ND	ND	ND	ND	ND
1,2 TR DICHLORO ETHENE	ND	ND	ND	ND	ND	ND	ND
1,1 DICHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND
CHLOROFORM	ND	ND	ND	ND	ND	ND	ND
1,2 CIS DICHLORO ETHENE	ND	ND	ND	ND	ND	3.7	1.8
1,1,1 TRICHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND
CARBON TETRACHLORIDE	ND	ND	ND	ND	ND	ND	ND
1,2 DICHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND
TRICHLORO ETHENE	3.0	2.7	3.5	0.6	ND	1640	840
1,2 DICHLORO PROPANE	ND	ND	ND	ND	ND	ND	ND
BROMO DICHLORO METHANE	ND	ND	ND	ND	ND	ND	ND
CIS DICHLORO PROPENE	ND	ND	ND	ND	ND	ND	ND
TRANS DICHLORO PROPENE	ND	ND	ND	ND	ND	ND	ND
1,1,2 TRICHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND
TETRACHLORO ETHENE	ND	ND	ND	ND	ND	ND	ND
CHLOROBENZENE	ND	ND	ND	ND	ND	ND	ND
TETRACHLORO ETHANE	ND	ND	ND	ND	ND	ND	ND

ND INDICATES NOT DETECTED AT DETECTION LIMIT OF 0.5 UG/L-VAPOR FOR EACH COMPOUND

ANALYSES PERFORMED ON SITE IN TEG'S DOHS CERTIFIED MOBILE LABORATORY (CERT #1890)

ANALYSES PERFORMED BY: BARTON MOORE

DATA REVIEWED BY: BLAYNE HARTMAN

APPENDIX E

TEG/KES SVE REPORT



**KABIS
ENVIRONMENTAL
SERVICES**

(619) 794-6244

(619) 263-7043

432 N. Cedros Ave., Solana Beach, California

STE 132, 402 63rd St., San Diego, California

*Experts in Environmental
Assessment &
Remediation*

December 14, 1993

Project No.: 93111T

Mr. Darrell Richardson
Ensafe, Inc.
5724 Summer Trees Drive
Memphis, TN 38134

Subject: Report of Soil Vapor Extraction Pilot Test at Carrier
Air facility, Collierville, TN.

Dear Darrell,

The following information regarding a report of soil vapor extraction pilot test (SVEPT) is provided at your request, September 28, 1993. We mobilized from two TEG locations to complete the field portion of the project; on November 28, 1993 we mobilized from Solana Beach, California and on December 1, 1993 we mobilized from Marietta Georgia, converging on the site on December 1, 1993. TEG's Mobil Laboratory was on-site with our mobile soil vapor extraction (SVE) test bed on December 2, 1993. Total field time, including chemical analyses of SVEPT and alternate SVE System in the northwest corner of the Carrier Air site, and SVEPT at locations A, B & C took approximately fourteen hours. The time saved by using a mobile test bed, in lieu of on-site construction, was approximately six man-days.

The site will support SVE; following is a description of our activities, methods and materials, and a compilation of our test analysis results and interpretations.

PROJECT DESCRIPTION

The project site is located just south of the southwest corner of Byhalia road and Highway 74, adjacent to the Collierville municipal well system, in Collierville, Tennessee. The site is host to the Carrier Air Conditioning Systems Manufacturing Plant. This site has been identified by the Environmental Protection Agency (EPA) as a Superfund Site. Among the site contaminants to be quantified and remediated are, 1,1,1 trichloroethane, 1,1,1 trichloroethene, dichloroethane, vinyl chloride, and the degradation products of these contaminants. Due to the nature of the discovered contaminants, the EPA has determined that Soil Vapor Extraction is the best available technology for remediation of this site.

REMEDIAL TECHNOLOGY DESCRIPTION

Soil vapor extraction is used for the remediation of soils contaminated with volatile organic compounds (VOC's). Soil vapor extraction (SVE) is the soil remedial

technology of choice in almost every case where soil contamination is less than 45 feet below the surface. SVE may also be used, under certain circumstances of highly porous soils, in deep applications, up to 200 feet below the local ground surface.

Pilot tests are typically conducted prior to design of SVE systems to assess soil permeability to gas, vapor flow rates, subsurface vacuum distribution, contaminant concentration locations, etc. This information can then be used in SVE remediation modeling to determine SVE design parameters such as contaminant removal rates, effective radius of influence, the design wellhead vacuum, and total system vapor flow rate. These design parameters ensure an efficient, cost-effective SVE remediation system.

It is worthy of note, that SVE is a process which requires time to properly affect. Testing beyond a time period of two hours for shallow (above 50 feet below local grade) SVE has been found to produce no more significant data than tests running more than two hours. Formations which will respond well for SVE remediation, even minimally, will respond within the aforementioned two hours. Typically, a one- or two-point SVEPT will run between one and one and one-half hours.

TEST OBJECTIVES

Soil containing varying concentrations of volatile organic compounds can be remediated using the mass-transfer technique of soil vapor extraction. The feasibility and design of such remedial systems, however, requires information regarding the in-situ contaminant characteristics, concentration, and formational flow characteristics. To acquire this data, soil vapor extraction pilot study testing is conducted.

Formations of varying thicknesses and varying permeabilities are placed under the influence of a vacuum source. Surrounding piezometers placed at various distances (generally at the same depth and screened interval) are sampled for vacuum influence using a magnahelic gauge. SVE testing is performed to acquire actual, in-situ data which may be used for the design of SVE systems. In-situ data are more accurate than the use of tables or graphs for the estimation of gas permeability and conductivity.

MATERIALS AND METHODS

Well Installation and Construction Six two-inch-diameter SVE wells were installed at the site, by EnSafe, Inc., in soil formations to depths appropriate to the localized contamination. The SVE wells were constructed from PVC, consisting of ten feet of 0.010-inch slots, screened from the bottom of each well, and the remaining portion of the well being solid casing. Clean, No. 30 silica sand was packed around the screened portion of the well to approximately 12 inches above the screened interval. Granular, hydrated bentonite was placed on top of the silica sand to within four feet of the surface where a cement-bentonite grout seal was placed to present a positive surface seal and

sturdy engineering base for the above-ground portion of the SVE well. Three one-inch-diameter PVC monitoring piezometers (MPs) were installed at varying distances from each SVE well. The MPs were constructed with two and one half feet of 0.010" slots, the remainder being solid casing. Construction and completion was conducted in the same manner as the SVE wells.

Vacuum Source Test Bed A rotary-vane, regenerative blower (RVRB), capable of generating a vacuum equivalent to approximately 128 CFM at 70 inches of water, was mounted to a 4-foot by 5-foot tote-trailer. The blower was powered with a 2.8hp, 100VAC electric motor, wired to single-phase operation. The blower/compressor was constructed from cast iron and was equipped with an aluminum rotary vane to preclude the potential for spark production in a potentially explosive environment. The blower was plumbed to a 30-gallon activated granular carbon (AGC) canister at the vacuum side. A vacuum gauge calibrated to a full-scale reading of 30-inches of mercury was installed between the AGC canister and the RVRB; the vacuum was regulated using a single ball-valve choke mounted in-line with the vacuum gauge. The AGC canister was plumbed to the SVE well under test. The exhaust, after AGC scrubbing, was vented to atmosphere at approximately 9 ft above local ground level. This arrangement ensured capture of any air contaminants produced by the test prior to entry into the blower, thus ensuring the intrinsic explosion resistance of the system. Power for the test bed was supplied by a 4kW gasoline-powered generator mounted to the trailer.

Preliminary Data Prior to the SVE pilot study testing, Shelby tube samples of the target strata were collected and mechanically analyzed by method 9100 as established by the third edition of EPA Manual SW-846 and in general compliance with the American Society for Testing and Materials (ASTM) method D-5084-90. These methods established the wet density, dry density, percent moisture content (by dry weight) and the coefficient of permeability expressed in centimeters per second. This information was necessary to evaluate the flow characteristics of the targeted strata.

SVE Pilot Test The SVE test at the site was conducted using a one-point variation of the standard two-point test due to the unique SVE well - MP installation configuration at the site. A single, 2-inch-diameter vapor extraction well, central to an array of vacuum induction monitoring piezometers, was placed under a constant vacuum at time zero (0). Within approximately 30 minutes from time 0, the surrounding piezometers, screened in the formation to be tested, are monitored for vacuum inductance using a sensitive magnahelic gauge. The readings from each monitoring piezometer were noted on a field test form and recorded every 30 minutes until apparent stability or 90 minutes was reached. To further evaluate the effectiveness of the SVEPT, soil vapor samples were withdrawn at regular intervals and analyzed, on-site for the constituents previously described.

Mobile Laboratory Analysis *Soil Gas Sampling* - Soil vapor was withdrawn from the intake manifold prior to entry into the AGC canister through a standard septum, using a 20 cc syringe connected via an on-off valve. The first 40 cc of gas are discarded to flush

the syringe and fill it with in-situ soil vapor. The next 20 cc of gas are withdrawn in the syringe, plugged, and immediately transferred to the mobile lab for analysis within minutes of collection. Additional soil vapor samples may be collected and stored in gas-tight containers as desired.

Flushing & Decontamination Procedures - To minimize the potential for cross-contamination between samples, sampling syringes are opened and exposed to outside air on a clean surface to allow any volatiles to escape after each use. If concentrations greater than 100 ppmv are detected for any compound (except methane), the syringe is discarded.

Analytical and QA/QC Procedures - Procedures for type and use of instrument, its calibration, and quality control may be found in the attachments to this report.

SVEPT Data Evaluation A flow rate may be derived from evaluation of pressure vacuum data collected at defined distances from the extraction well in a one-point SVE pilot study test. The value for this constant may be determined by collecting a pressure reading at h for radius r from an extraction source at two points:

$$P_1, r_1 : P_2, r_2$$

Such that:

$$P_2^2 - P_1^2 = \frac{-Q_m \mu R T}{p_w K h} \ln(r_2 - r_1)$$

Where:

Q_m = Flow Rate

μ = Viscosity of Air

R = Gas Constant

T = Temperature, °K

w = Molecular Weight of Air

K = Soil/Air Permeability

h = Formation Thickness

in lieu of the fact that piezometers were placed at varying depths and at varying radii from each extraction source, only P1 and R1 were used in calculation.

Note that:

$$\frac{Q_m mRT}{p_w K h} = \text{Constant for a given flow rate}$$

Once the constant has been determined, a draw-down vs. distance curve may be constructed for optimal design operation.

SVE PILOT TEST RESULTS

The previously related mathematical model was used to evaluate the results of the field test and estimate flows generated by the test. Results of the SVE test conclude that vertical soil vapor extraction is feasible at the subject site within the fine-grained sand formation located at approximately 28- to 30-feet below local grade. Calculated (estimated) flow rates based on magnahelic readings are between 2.18×10^{-2} cfh at monitoring point A3, and 2.73×10^{-2} cfh at monitoring point B7. See data compilation table attached to this report.

The clay formation located at approximately 12 to 25-feet below local grade is more conducive to simple mass-transfer remediation using gallery-type, high-volume flow, horizontal arrays. Flows within the clay formation were estimated to be between 1.20×10^{-1} cfh at monitoring point A6 and 4.43×10^{-4} cfh at monitoring point B6. See data compilation table attached to this report.

A site plan indicating the location of the three areas for SVEPT is attached.

LABORATORY ANALYSIS RESULTS

All analysis results were delivered to EnSafe personnel on-site.

RESULTS EVALUATION

Separate graphs of all of the test results have been provided (attached). In most cases, departures from the expected drop-off of flow with distance, normal to "in-line" MP configurations, have been pointed out on the graphs along with a plausible explanation for the aberration. Essentially, aberrations from "normal" radius of influence curves may be accounted for by any combination of the following;

1. influence of a manmade trench in close proximity to the MP,
2. cross-over influence by two MP's installed in close proximity but at varying depths,

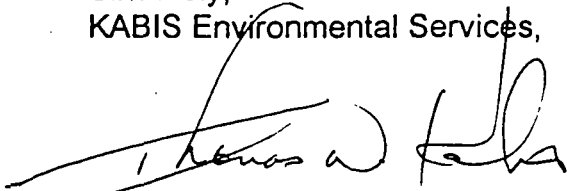
3. influence of deep root structures of animal burrows,
4. variation in horizontal stratigraphic composition,
5. variation in vertical stratigraphic composition.

Aberrations in graphed data must be viewed as "localized" phenomena and should be ignored in the over-all design of SVE systems.

It should be pointed out, that SVE wells and MP's, for future tests, should be installed in-line, and all MP's should be installed at the same depth and have the same screened interval. This will remove some of the aberrant data results encountered in this test. I would be happy to provide you with the SVE Pilot Test chapter from my book, "Environmental Investigation Guidelines", 1990, if you wish.

If you have any questions or require additional information, please call us.

Sincerely,
KABIS Environmental Services,

A handwritten signature in black ink, appearing to read 'Thomas W. Kabis', written over a horizontal line.

Thomas W. Kabis
Remediation Specialist,
Hydrogeologist

Soil Vapor Analytical Methodology

Halogenated, TPH, & Aromatic Hydrocarbons

Operating Conditions and Instrumentation

Instrument: Shimadzu GC-14 Gas Chromatograph

Column: 75 meter DB-624, megabore capillary.

Carrier flow: Helium at 15 ml/min.

Detectors: Photoionization/Hall (ElCD) detectors in series.

Detectors: Flame ionization detector on separate column.

Column oven: 45°C for 2 min, 45°C to 175°C at 5°C/min.

Standard Preparation

Primary (stock) standards (100 mg/l of each component in methanol) are purchased from certified suppliers.

Secondary (Working) Standards (10 ug/ml) are made at least monthly by diluting primary standard 10 times (400 ul primary to 4 ml solvent).

Neat (Pure) Standards of many compounds are carried in the laboratory to enable on-site preparation of compound-specific standards as appropriate.

QC Check Sample is prepared at the midpoint concentration from a standard purchased from a source different than the primary standards.

Lot numbers and preparations of all standards are recorded on a log sheet in kept in the mobile laboratory.

Instrument Calibration

Three point calibration curves for each target component are prepared by analyzing low, mid, & high calibration standards as follows:

Low Calibration Standard: 1 ng per component = 1 ug/l-vapor

Mid Calibration Standard: 10 ng per component = 10 ug/l- vapor

High Calibration Standard: 100 ng per component = 100 ug/l- vapor

Continuing Calibration

Continuing Calibration is performed at the start of each day by injecting a mid-range calibration standard. Acceptable continuing calibration agreement: +/- 15% to the calibration curve.

QC Check Samples

A QC check sample, prepared from an independent source, is analyzed in the morning and in the afternoon. Acceptable agreement is +/-20% to the calibration curve.

Injection of Soil Vapor Samples

Vapor samples are withdrawn from the sampling syringe with a 1 cc syringe and injected directly into a sampling port on the gas chromatograph. The injection syringe is flushed 2 times with the sample prior to injection. Injection syringes are baked between injections and discarded if values greater than 100 ppmv of any compound are measured.

Compound Confirmation

All 8010/8020 analyses are performed with PID/Hall detectors in series on parallel 60 to 100 meter columns following EPA Method 8021 protocols. This configuration gives required separation and

dual-detector confirmation. In addition, a second analysis is done on all samples using a second column with an FID detector.

Blanks

Blanks are analyzed at the start of each day and more often as appropriate depending upon the measured concentrations. Typically, when values exceeding 100 ppmv are encountered, additional blanks may be analyzed.

Duplicates

Duplicate samples are analyzed when inconsistent data are observed or as requested by the client or regulatory agency. Because soil vapor duplicates can vary widely, TEG's nominal RPD acceptance criteria is +/- a factor of 2.

Sample Identification

Each sample is given a unique ID specifying location & depth.

Sample Holding Time

Soil vapor samples are not stored, but analyzed immediately upon collection.

Calculation of Soil Vapor Concentrations

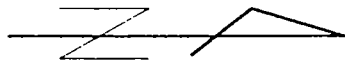
Micrograms/liter-vapor (ug/l-vapor): $\text{ng injected/cc of vapor injected}$.

Parts per million volume (ppmv): $\text{ug/l-vapor} * R/M_w$

R is the universal gas constant (24 at ambient Temp)

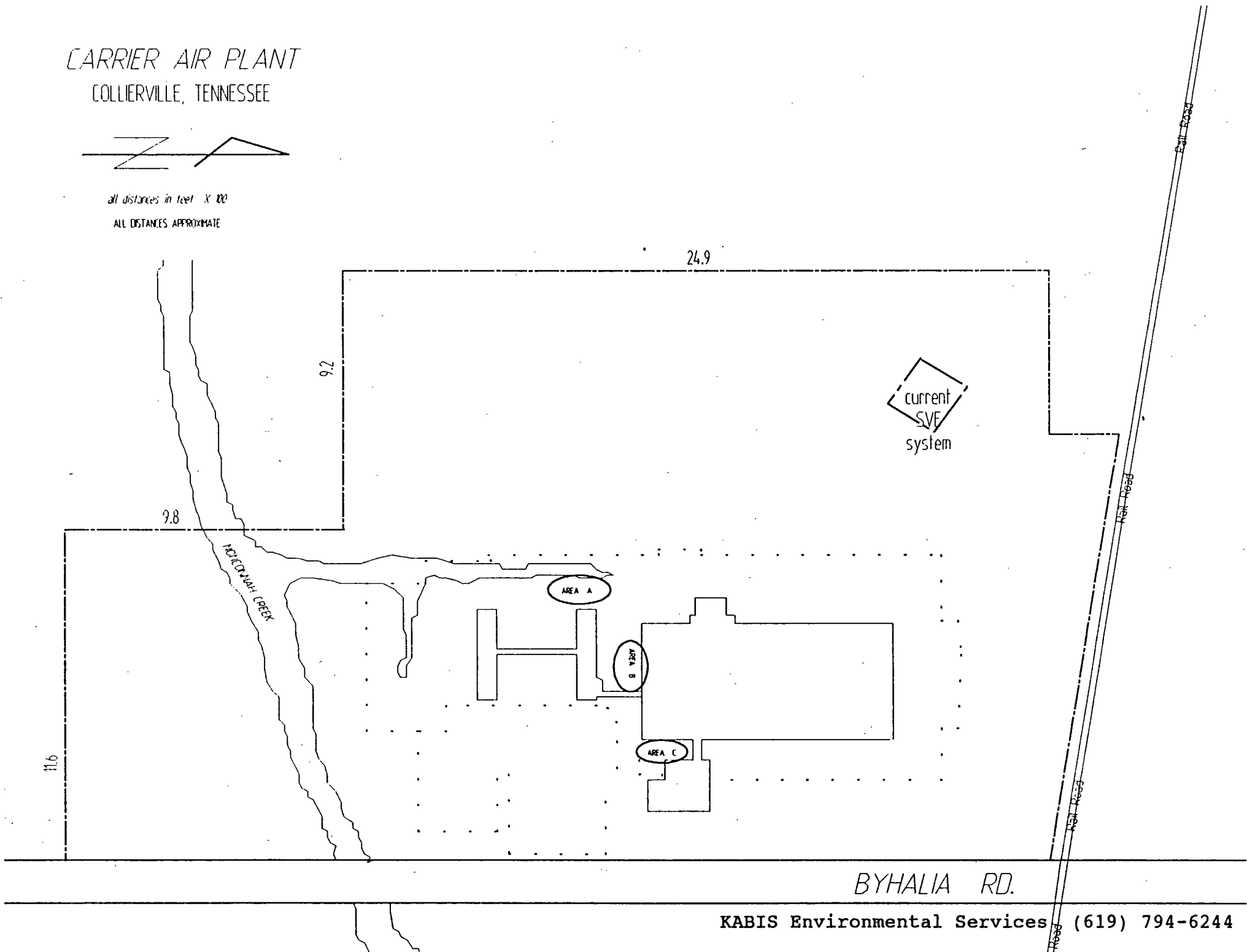
M_w is the molecular weight of each compound

CARRIER AIR PLANT
COLLIERVILLE, TENNESSEE



all distances in feet X 100

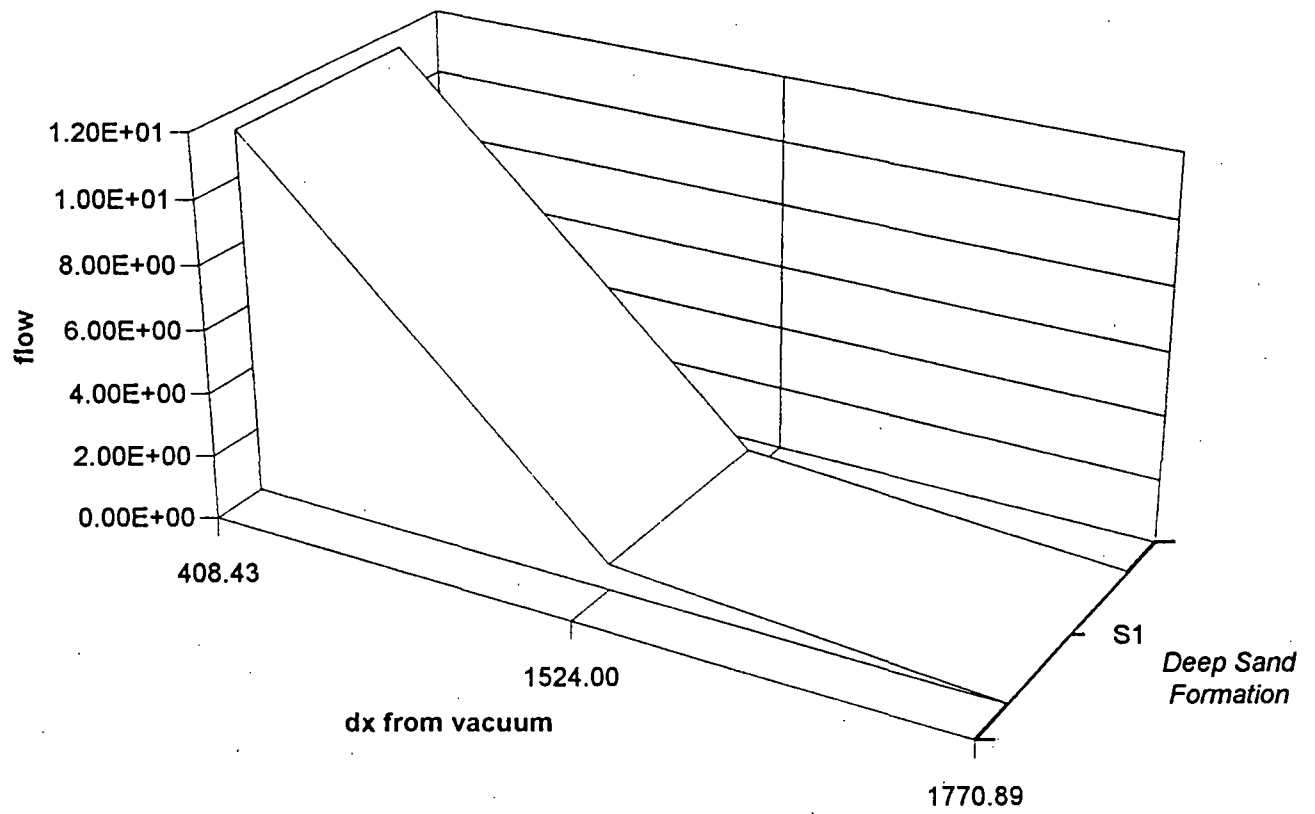
ALL DISTANCES APPROXIMATE



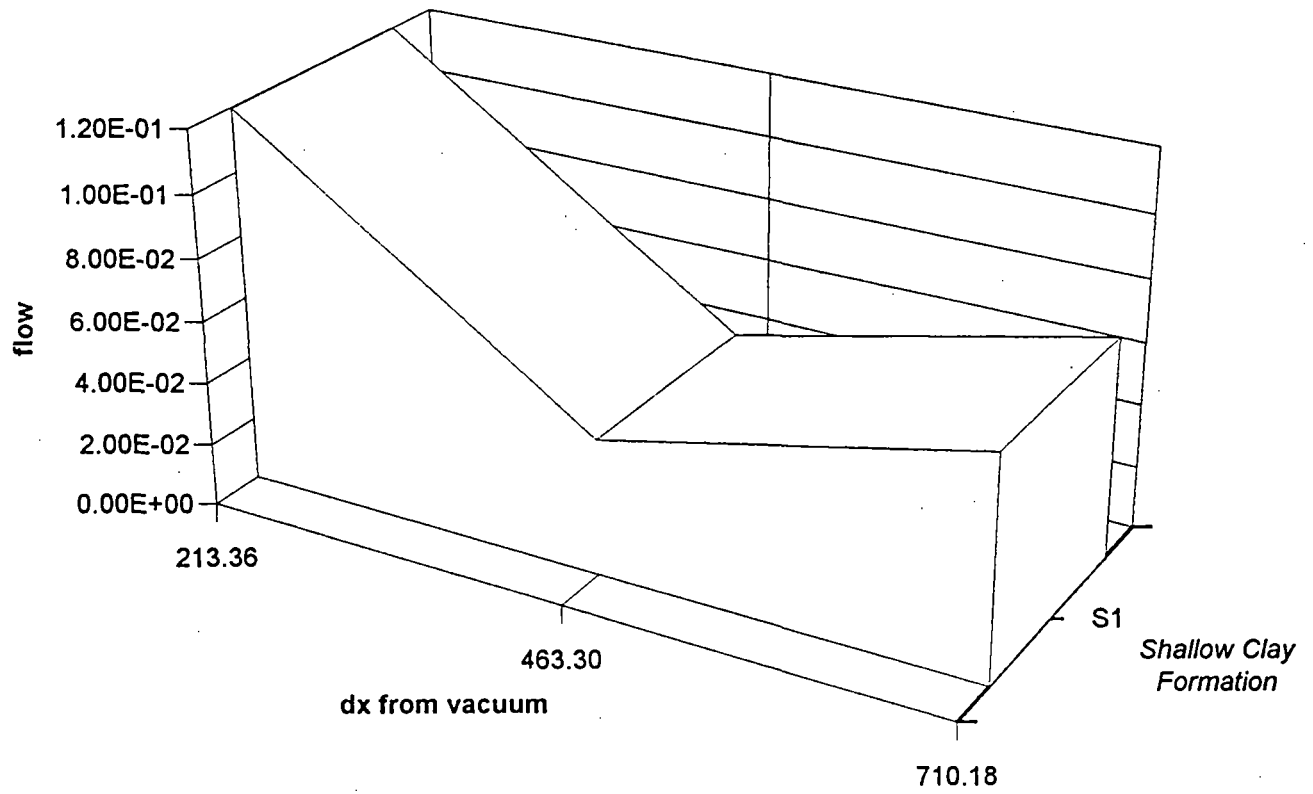
EVALUATION OF FLOW

sample point	screened intv. - h cm	pi * wKh cc/s	permeability - K cm/s	uRT const	r1 cm	ln[r1] cm	p1 cm H2O	(p1)2 cm H2O	flow - Qm cc/s gas	flow - Qm cfm	flow - Qm cfh
A3	7.62E+01	5.08E-01	2.38E-04	4.50E+06	1770.89	7.48	0.65	0.42	6.37E-09	3.64E-04	2.18E-02
A4	7.62E+01	5.25E-03	2.46E-06	4.50E+06	463.30	6.14	8.13	66.06	1.26E-08	7.16E-04	4.30E-02
A5	7.62E+01	5.08E-01	2.38E-04	4.50E+06	408.43	6.01	13.33	177.69	3.33E-06	1.90E-01	1.14E+01
A6	7.62E+01	5.25E-03	2.46E-06	4.50E+06	213.36	5.36	12.68	160.78	3.50E-08	2.00E-03	1.20E-01
A7	7.62E+01	5.08E-01	2.38E-04	4.50E+06	1524.00	7.33	3.90	15.22	2.34E-07	1.34E-02	8.02E-01
A8	7.62E+01	5.25E-03	2.46E-06	4.50E+06	710.18	6.57	10.73	115.11	2.04E-08	1.17E-03	7.00E-02
B3	7.62E+01	2.35E+00	1.10E-03	4.50E+06	1584.96	7.37	5.85	34.25	2.43E-06	1.38E-01	8.31E+00
B4	7.62E+01	7.68E-04	3.60E-07	4.50E+06	457.20	6.13	4.55	20.72	5.77E-10	3.30E-05	1.98E-03
B5	7.62E+01	2.35E+00	1.10E-03	4.50E+06	411.48	6.02	15.28	233.51	2.02E-05	1.16E+00	6.93E+01
B6	7.62E+01	7.68E-04	3.60E-07	4.50E+06	152.40	5.03	1.95	3.81	1.29E-10	7.38E-06	4.43E-04
B7	7.62E+01	2.35E+00	1.10E-03	4.50E+06	996.70	6.90	32.51	1057.03	7.99E-05	4.56E+00	2.74E+02
B8	7.62E+01	7.68E-04	3.60E-07	4.50E+06	579.12	6.36	3.90	15.22	4.08E-10	2.33E-05	1.40E-03
C3	7.62E+01	2.35E+00	1.10E-03	4.50E+06	1463.04	7.29	13.66	186.46	1.34E-05	7.62E-01	4.57E+01
C4	7.62E+01	7.68E-04	3.60E-07	4.50E+06	457.20	6.13	14.23	202.41	5.64E-09	3.22E-04	1.93E-02
C5	7.62E+01	2.35E+00	1.10E-03	4.50E+06	868.68	6.77	15.61	243.55	1.88E-05	1.07E+00	6.43E+01
C6	7.62E+01	7.68E-04	3.60E-07	4.50E+06	152.40	5.03	9.43	88.89	3.02E-09	1.72E-04	1.03E-02
C7	7.62E+01	2.35E+00	1.10E-03	4.50E+06	1021.08	6.93	32.51	1057.03	7.96E-05	4.54E+00	2.73E+02
C8	7.62E+01	7.68E-04	3.60E-07	4.50E+06	609.60	6.41	9.10	82.86	2.21E-09	1.26E-04	7.55E-03

AREA A

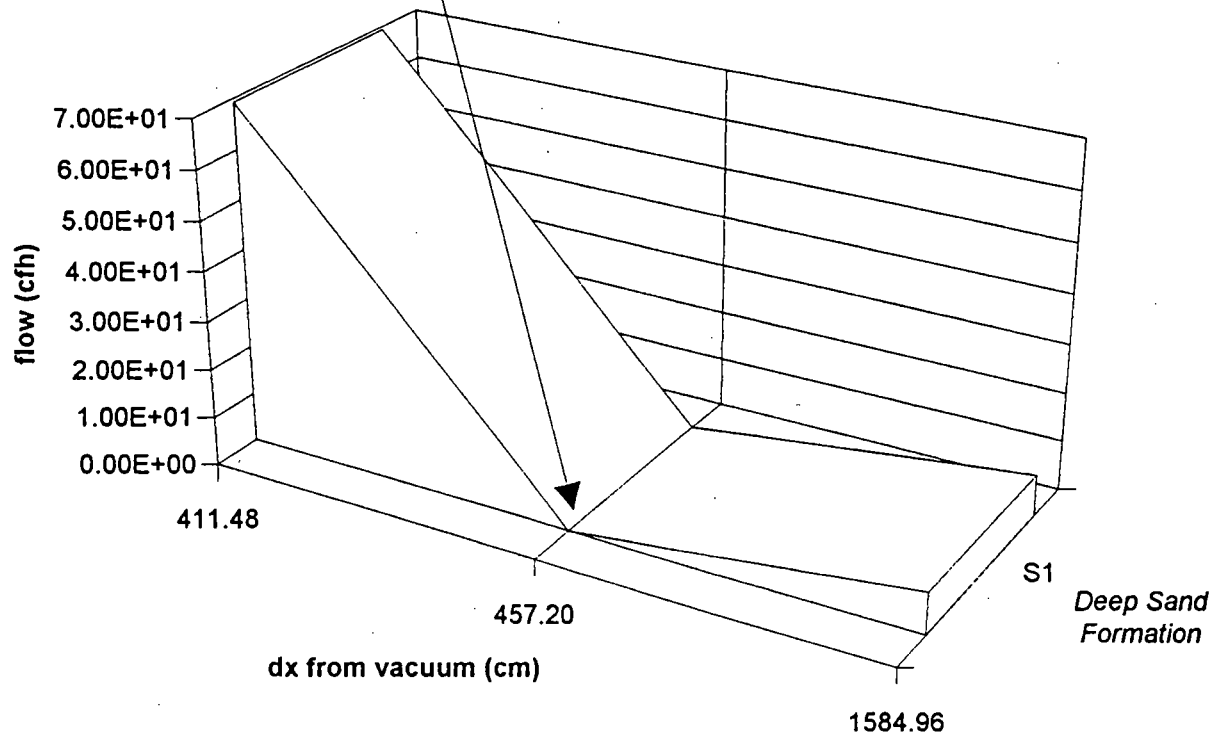


AREA A

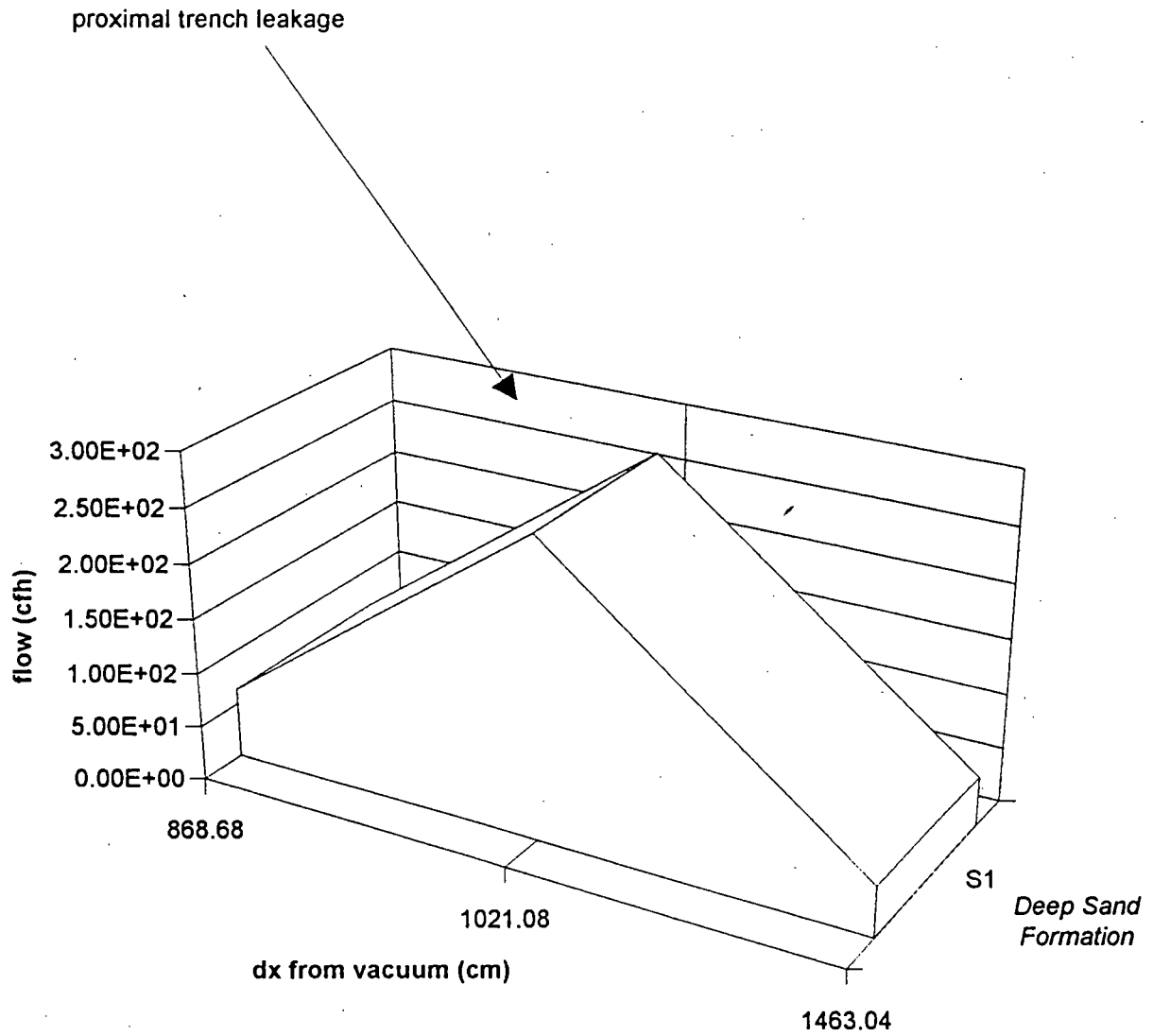


AREA B

horizontal variation in formation

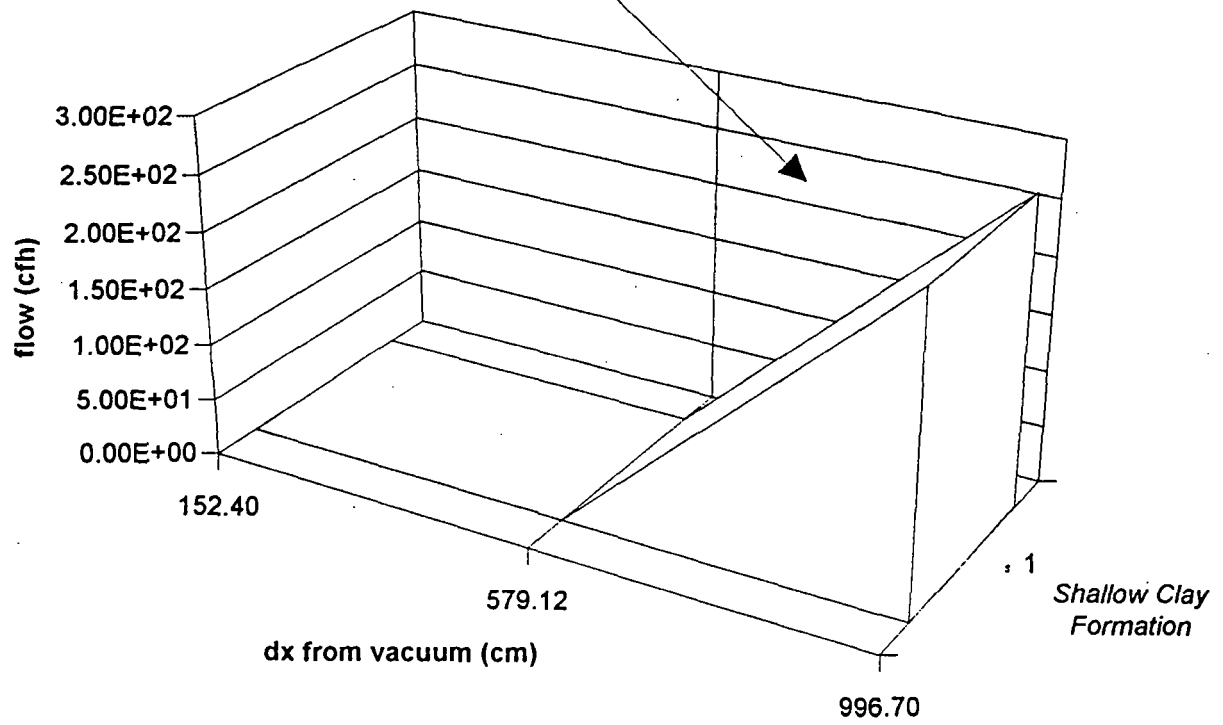


AREA C

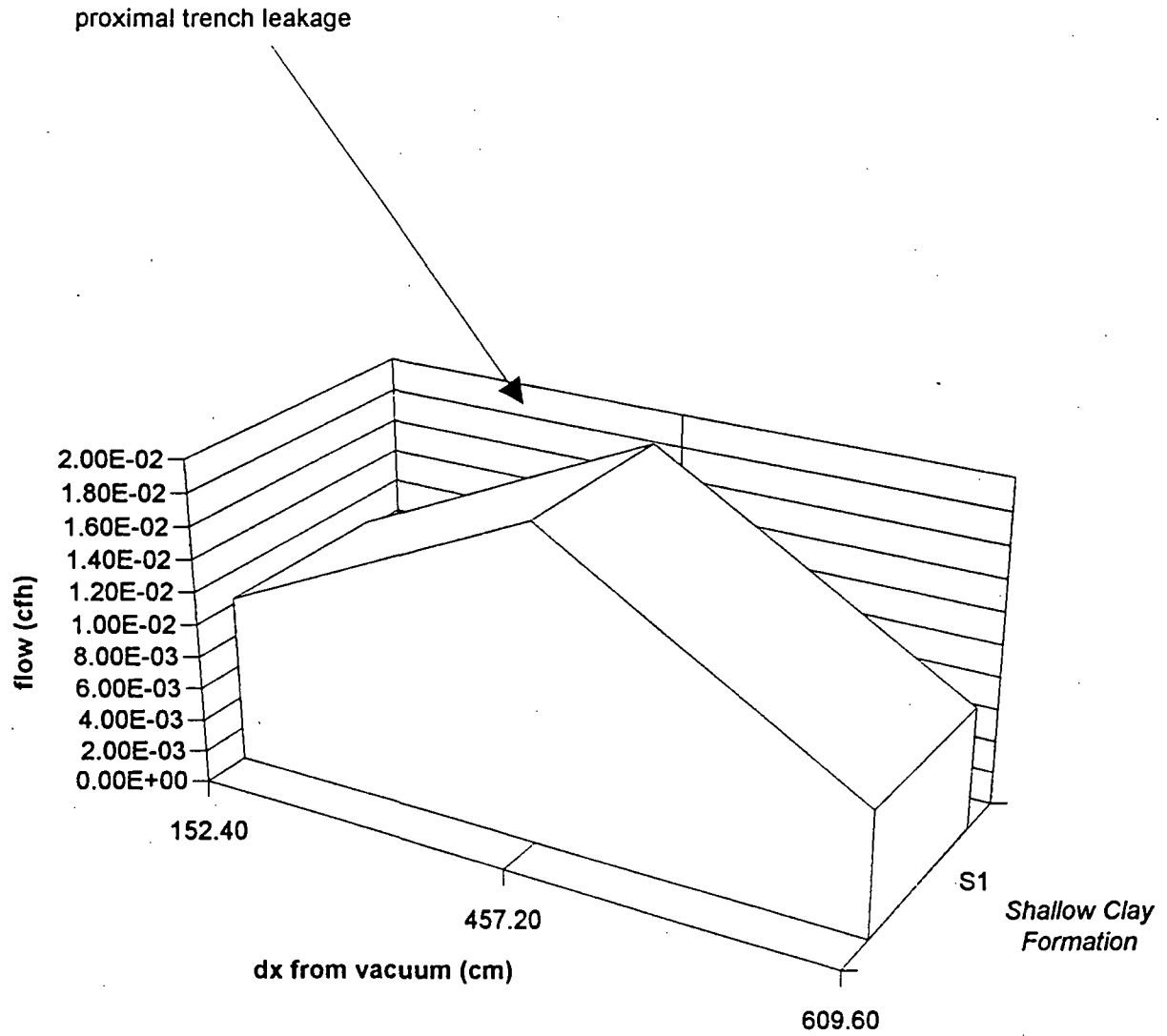


AREA B

proximal trench leakage



AREA C



F

APPENDIX F

EMISSION RATE CALCULATIONS

Emission Rate Calculations

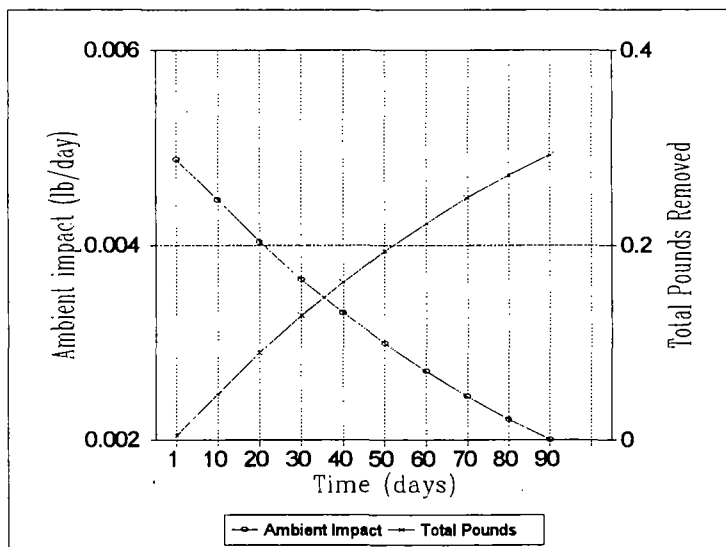
Site: CCSVE1A2

Date: Jan-94

Given:			Time (days)	Ce (g/m ³)	AI (lb/day)	M (lbs)
Co	0.12785	(ppm)				
mw	131.4					
k	0.01	(1/day)				
Q	80	(cfm)				
Co = Influent Concentration			1	0.0007	0.0049	0.0049
mw = Molecular Weight			10	0.0006	0.0045	0.0469
k = Decay Rate Coefficient			20	0.0006	0.0040	0.0894
Q = Exhaust Flowrate			30	0.0005	0.0037	0.1278
Ce = Emission rate			40	0.0005	0.0033	0.1625
AI = Ambient Impact			50	0.0004	0.0030	0.1939
M = Total pounds removed			60	0.0004	0.0027	0.2224
			70	0.0003	0.0024	0.2481
			80	0.0003	0.0022	0.2714
			90	0.0003	0.0020	0.2925

Equations:

1.	Ce =	$\frac{Co \cdot e^{-kt} \text{ (m}^3\text{)}}{1,000,000 \text{ (m}^3\text{)}}$	$\frac{mw \text{ (g)}}{(g\text{-mole})}$	$\frac{(g\text{-mole})}{24.5 \text{ (L)}}$	$\frac{1000 \text{ (L)}}{(m^3)}$
2.	AI =	$\frac{Ce \text{ (g)}}{(m^3)}$	$\frac{0.0283 \text{ (m}^3\text{)}}{(ft^3)}$	$\frac{Q \text{ (ft}^3\text{)}}{(min)}$	$\frac{1440 \text{ (min)}}{(day)}$
					$\frac{(lb)}{454 \text{ (g)}}$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data.
3. $ppmv = \mu g/l\text{-vapor} \times 18265$

Emission Rate Calculations

Site: CCSVE1A3

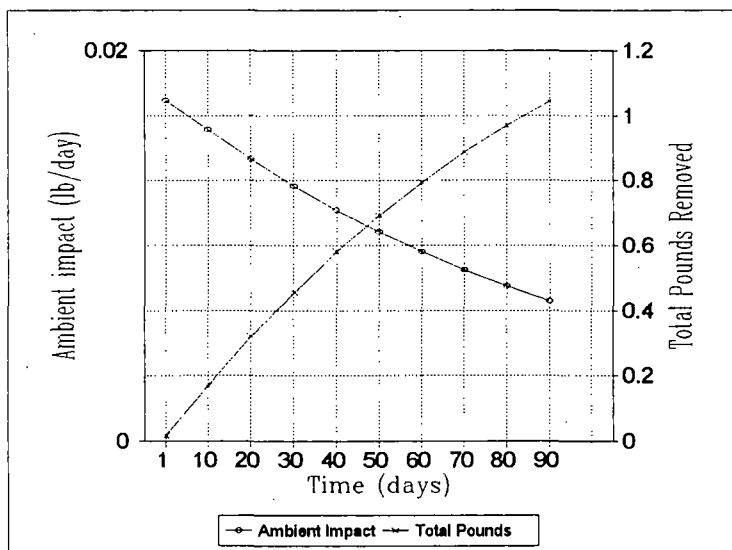
Date: Jan-94

Given:		Time (days)	Ce (g/m ³)	AI (lb/day)	M (lbs)
Co	0.45663 (ppm)				
mw	131.4				
k	0.01 (1/day)				
Q	80 (cfm)				
Co = Influent Concentration		1	0.0024	0.0174	0.0175
mw = Molecular Weight		10	0.0022	0.0159	0.1675
k = Decay Rate Coefficient		20	0.0020	0.0144	0.3191
Q = Exhaust Flowrate		30	0.0018	0.0130	0.4563
Ce = Emission rate		40	0.0016	0.0118	0.5804
AI = Ambient Impact		50	0.0015	0.0107	0.6927
M = Total pounds removed		60	0.0013	0.0097	0.7943
		70	0.0012	0.0087	0.8863
		80	0.0011	0.0079	0.9695
		90	0.0010	0.0072	1.0447

Equations:

$$1. Ce = \frac{Co \cdot e^{-kt} (m^3)}{1,000,000 (m^3)} \cdot \frac{mw (g)}{(g-mole)} \cdot \frac{(g-mole)}{24.5 (L)} \cdot \frac{1000 (L)}{(m^3)}$$

$$2. AI = \frac{Ce (g)}{(m^3)} \cdot \frac{0.0283 (m^3)}{(ft^3)} \cdot \frac{Q (ft^3)}{(min)} \cdot \frac{1440 (min)}{(day)} \cdot \frac{(lb)}{454 (g)}$$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data
3. ppmv = ug/l-vapor x .18265

Emission Rate Calculations

Site: CCSVE1B1

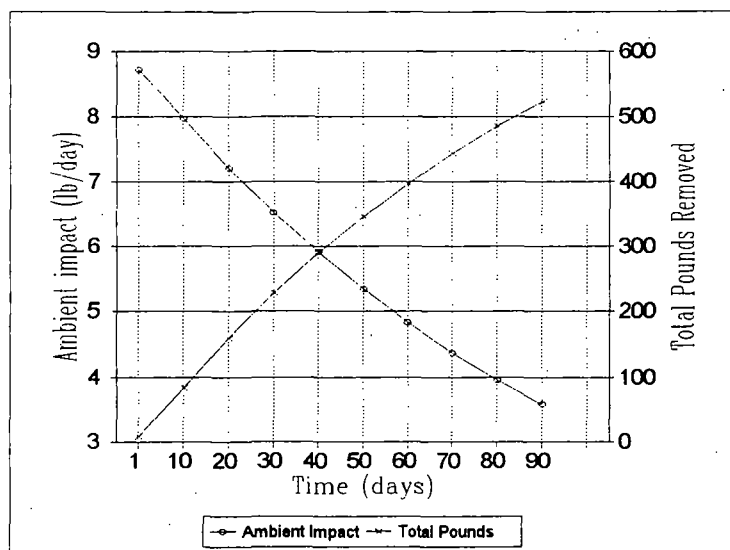
Date: Jan-94

Given:			Time	Ce	AI	M
			(days)	(g/m ³)	(lb/day)	(lbs)
Co	228.312	(ppm)				
mw	131.4					
k	0.01	(1/day)				
Q	80	(cfm)				
Co = Influent Concentration			1	1.2123	8.7148	8.759
mw = Molecular Weight			10	1.1080	7.9647	83.766
k = Decay Rate Coefficient			20	1.0025	7.2068	159.560
Q = Exhaust Flowrate			30	0.9071	6.5210	228.142
Ce = Emission rate			40	0.8208	5.9004	290.198
AI = Ambient Impact			50	0.7427	5.3389	346.348
M = Total pounds removed			60	0.6720	4.8309	397.154
			70	0.6081	4.3711	443.126
			80	0.5502	3.9552	484.723
			90	0.4978	3.5788	522.361

Equations:

$$1. Ce = \frac{Co \cdot e^{-kt} \text{ (m}^3\text{)}}{1,000,000 \text{ (m}^3\text{)}} \cdot \frac{mw \text{ (g)}}{\text{(g-mole)}} \cdot \frac{\text{(g-mole)}}{24.5 \text{ (L)}} \cdot \frac{1000 \text{ (L)}}{\text{(m}^3\text{)}}$$

$$2. AI = \frac{Ce \text{ (g)}}{\text{(m}^3\text{)}} \cdot \frac{0.0283 \text{ (m}^3\text{)}}{\text{(ft}^3\text{)}} \cdot \frac{Q \text{ (ft}^3\text{)}}{\text{(min)}} \cdot \frac{1440 \text{ (min)}}{\text{(day)}} \cdot \frac{\text{(lb)}}{454 \text{ (g)}}$$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data.
3. $ppmv = \mu g/l \text{-vapor} \times .18265$

Emission Rate Calculations

Site: CCSVE2B1

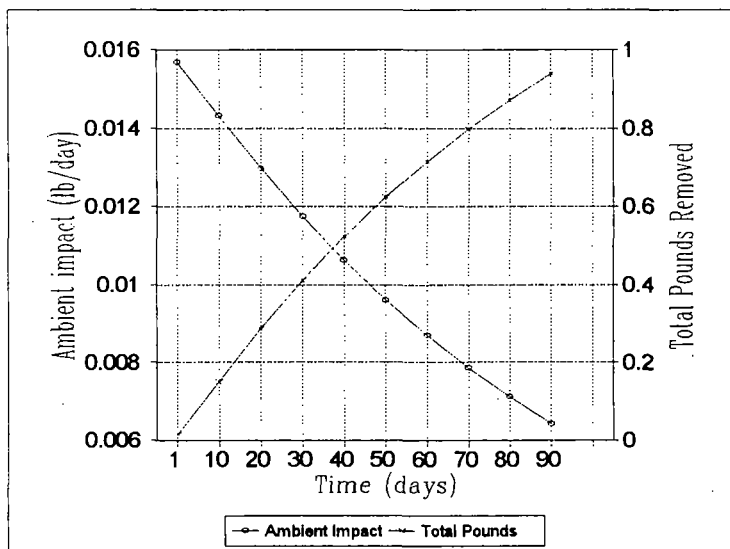
Date: Jan-94

Given:			Time (days)	Ce (g/m ³)	AI (lb/day)	M (lbs)
Co	0.54795	(ppm)				
mw	131.4					
k	0.01	(1/day)				
Q	60	(cfm)				
Co = Influent Concentration			1	0.0029	0.0157	0.016
mw = Molecular Weight			10	0.0027	0.0143	0.151
k = Decay Rate Coefficient			20	0.0024	0.0130	0.287
Q = Exhaust Flowrate			30	0.0022	0.0117	0.411
Ce = Emission rate			40	0.0020	0.0106	0.522
AI = Ambient Impact			50	0.0018	0.0096	0.623
M = Total pounds removed			60	0.0016	0.0087	0.715
			70	0.0015	0.0079	0.798
			80	0.0013	0.0071	0.873
			90	0.0012	0.0064	0.940

Equations:

$$1. Ce = \frac{Co \cdot e^{-kt} (m^3)}{1,000,000 (m^3)} \cdot \frac{mw (g)}{(g \cdot mole)} \cdot \frac{1000 (L)}{24.5 (L)} \cdot \frac{1}{(m^3)}$$

$$2. AI = \frac{Ce (g)}{(m^3)} \cdot \frac{0.0283 (m^3)}{(ft^3)} \cdot \frac{Q (ft^3)}{(min)} \cdot \frac{1440 (min)}{(day)} \cdot \frac{(lb)}{454 (g)}$$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data.
3. $ppmv = ug/l \cdot vapor \times .18265$

Emission Rate Calculations

Site: CCSVE2B2

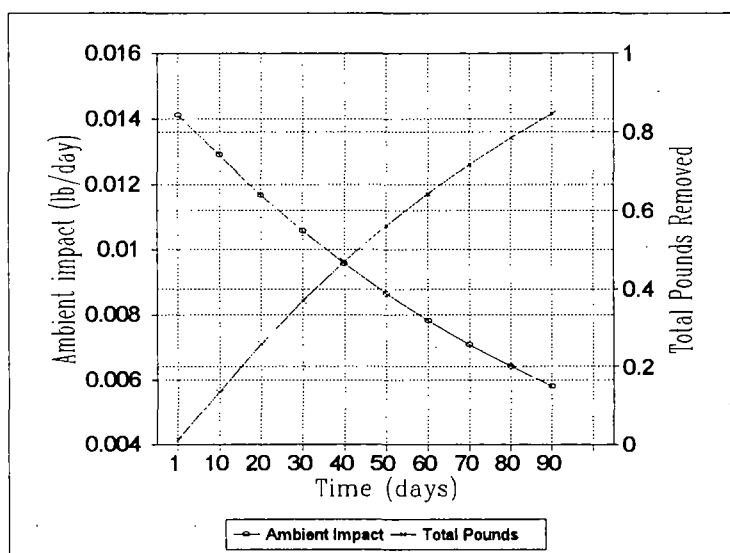
Date: Jan-94

Given:			Time (days)	Ce (g/m ³)	AI (lb/day)	M (lbs)
Co	0.49318	(ppm)				
mw	131.4					
k	0.01	(1/day)				
Q	60	(cfm)				
Co = Influent Concentration			1	0.0026	0.0141	0.014
mw = Molecular Weight			10	0.0024	0.0129	0.136
k = Decay Rate Coefficient			20	0.0022	0.0117	0.258
Q = Exhaust Flowrate			30	0.0020	0.0106	0.370
Ce = Emission rate			40	0.0018	0.0096	0.470
AI = Ambient Impact			50	0.0016	0.0086	0.561
M = Total pounds removed			60	0.0015	0.0078	0.643
			70	0.0013	0.0071	0.718
			80	0.0012	0.0064	0.785
			90	0.0011	0.0058	0.846

Equations:

$$1. Ce = \frac{Co \cdot e^{-kt} (m^3)}{1,000,000 (m^3)} \cdot \frac{mw (g)}{(g-mole)} \cdot \frac{(g-mole)}{24.5 (L)} \cdot \frac{1000 (L)}{(m^3)}$$

$$2. AI = \frac{Ce (g)}{(m^3)} \cdot \frac{0.0283 (m^3)}{(ft^3)} \cdot \frac{Q (ft^3)}{(min)} \cdot \frac{1440 (min)}{(day)} \cdot \frac{(lb)}{454 (g)}$$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data.
3. ppmv = ug/l-vapor x .18265

Emission Rate Calculations

Site: CCSVE2B3

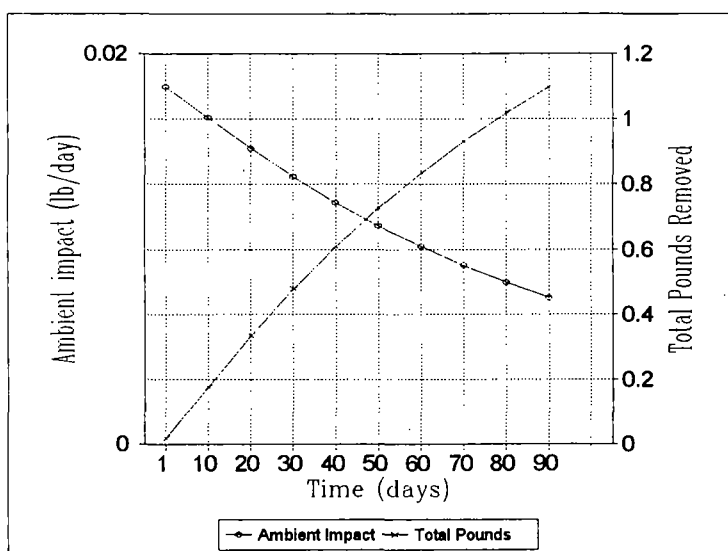
Date: Jan-94

Given:		Time (days)	Ce (g/m ³)	AI (lb/day)	M (lbs)
Co	0.63928 (ppm)				
mw	131.4				
k	0.01 (1/day)				
Q	60 (cfm)				
Co = Influent Concentration		1	0.0034	0.0183	0.018
mw = Molecular Weight		10	0.0031	0.0167	0.176
k = Decay Rate Coefficient		20	0.0028	0.0151	0.335
Q = Exhaust Flowrate		30	0.0025	0.0137	0.479
Ce = Emission rate		40	0.0023	0.0124	0.609
AI = Ambient Impact		50	0.0021	0.0112	0.727
M = Total pounds removed		60	0.0019	0.0101	0.834
		70	0.0017	0.0092	0.931
		80	0.0015	0.0083	1.018
		90	0.0014	0.0075	1.097

Equations:

$$1. \quad Ce = \frac{Co \cdot e^{-kt} \text{ (m}^3\text{)}}{1,000,000 \text{ (m}^3\text{)}} \cdot \frac{mw \text{ (g)}}{\text{(g-mole)}} \cdot \frac{\text{(g-mole)}}{24.5 \text{ (L)}} \cdot \frac{1000 \text{ (L)}}{\text{(m}^3\text{)}}$$

$$2. \quad AI = \frac{Ce \text{ (g)}}{\text{(m}^3\text{)}} \cdot \frac{0.0283 \text{ (m}^3\text{)}}{\text{(ft}^3\text{)}} \cdot \frac{Q \text{ (ft}^3\text{)}}{\text{(min)}} \cdot \frac{1440 \text{ (min)}}{\text{(day)}} \cdot \frac{\text{(lb)}}{454 \text{ (g)}}$$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data.
3. $ppmv = \mu g/l \text{-vapor} \times .18265$

Emission Rate Calculations

Site: CCSVE1C1

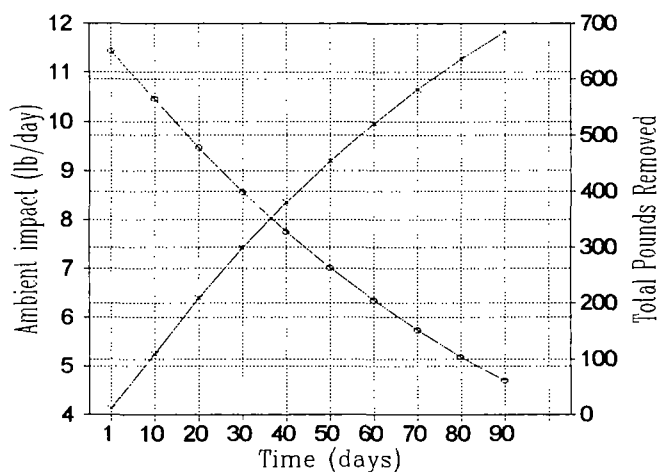
Date: Jan-94

Given:			Time (days)	Ce (g/m ³)	AI (lb/day)	M (lbs)
Co	299.546	(ppm)				
mw	131.4					
k	0.01	(1/day)				
Q	80	(cfm)				
Co = Influent Concentration			1	1.5906	11.4339	11.491
mw = Molecular Weight			10	1.4537	10.4498	109.901
k = Decay Rate Coefficient			20	1.3153	9.4553	209.344
Q = Exhaust Flowrate			30	1.1902	8.5555	299.323
Ce = Emission rate			40	1.0769	7.7414	380.740
AI = Ambient Impact			50	0.9744	7.0047	454.409
M = Total pounds removed			60	0.8817	6.3381	521.067
			70	0.7978	5.7350	581.382
			80	0.7219	5.1892	635.958
			90	0.6532	4.6954	685.339

Equations:

$$1. Ce = \frac{Co \cdot e^{-kt} (m^3)}{1,000,000 (m^3)} \cdot \frac{mw (g)}{(g-mole)} \cdot \frac{(g-mole)}{24.5 (L)} \cdot \frac{1000 (L)}{(m^3)}$$

$$2. AI = \frac{Ce (g)}{(m^3)} \cdot \frac{0.0283 (m^3)}{(ft^3)} \cdot \frac{Q (ft^3)}{(min)} \cdot \frac{1440 (min)}{(day)} \cdot \frac{(lb)}{454 (g)}$$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data.
3. $ppmv = \mu g/l-vapor \times .18265$

Emission Rate Calculations

Site: CCSVE1C2

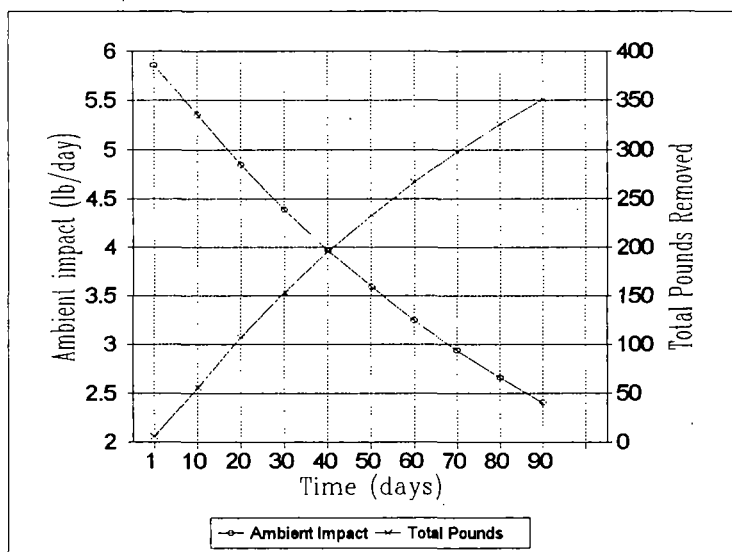
Date: Jan-94

Given:			Time (days)	Ce (g/m ³)	AI (lb/day)	M (lbs)
Co	153.426	(ppm)				
mw	131.4					
k	0.01	(1/day)				
Q	80	(cfm)				
Co = Influent Concentration			1	0.8147	5.8564	5.886
mw = Molecular Weight			10	0.7446	5.3523	56.291
k = Decay Rate Coefficient			20	0.6737	4.8430	107.225
Q = Exhaust Flowrate			30	0.6096	4.3821	153.312
Ce = Emission rate			40	0.5516	3.9651	195.013
AI = Ambient Impact			50	0.4991	3.5878	232.746
M = Total pounds removed			60	0.4516	3.2463	266.888
			70	0.4086	2.9374	297.781
			80	0.3697	2.6579	325.734
			90	0.3346	2.4050	351.028

Equations:

$$1. Ce = \frac{Co \cdot e^{-kt} \text{ (m}^3\text{)}}{1,000,000 \text{ (m}^3\text{)}} \cdot \frac{mw \text{ (g)}}{\text{(g-mole)}} \cdot \frac{\text{(g-mole)}}{24.5 \text{ (L)}} \cdot \frac{1000 \text{ (L)}}{\text{(m}^3\text{)}}$$

$$2. AI = \frac{Ce \text{ (g)}}{\text{(m}^3\text{)}} \cdot \frac{0.0283 \text{ (m}^3\text{)}}{\text{(ft}^3\text{)}} \cdot \frac{Q \text{ (ft}^3\text{)}}{\text{(min)}} \cdot \frac{1440 \text{ (min)}}{\text{(day)}} \cdot \frac{\text{(lb)}}{454 \text{ (g)}}$$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data.
3. ppmv = ug/l-vapor x .18265

Emission Rate Calculations

Site: CCSVE2C1

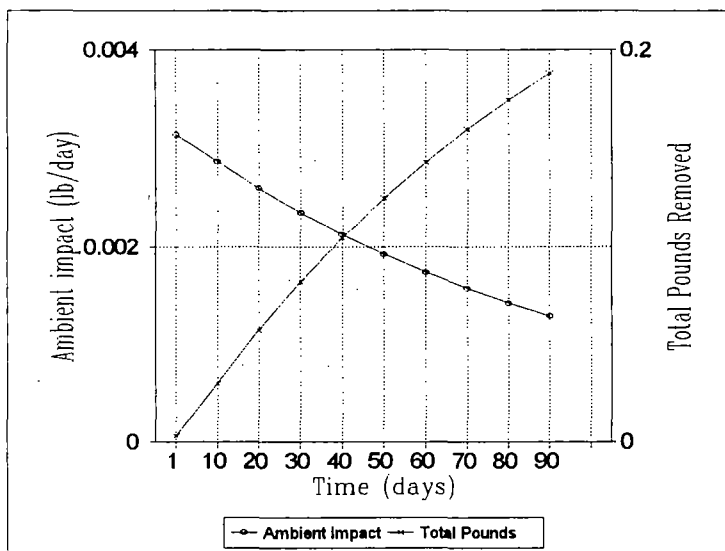
Date: Jan-94

Given:			Time (days)	Ce (g/m ³)	AI (lb/day)	M (lbs)
Co	0.10959	(ppm)				
mw	131.4					
k	0.01	(1/day)				
Q	60	(cfm)				
Co = Influent Concentration			1	0.0006	0.0031	0.003
mw = Molecular Weight			10	0.0005	0.0029	0.030
k = Decay Rate Coefficient			20	0.0005	0.0026	0.057
Q = Exhaust Flowrate			30	0.0004	0.0023	0.082
Ce = Emission rate			40	0.0004	0.0021	0.104
AI = Ambient Impact			50	0.0004	0.0019	0.125
M = Total pounds removed			60	0.0003	0.0017	0.143
			70	0.0003	0.0016	0.160
			80	0.0003	0.0014	0.175
			90	0.0002	0.0013	0.188

Equations:

$$1. Ce = \frac{Co \cdot e^{-kt} \text{ (m}^3\text{)}}{1,000,000 \text{ (m}^3\text{)}} \cdot \frac{mw \text{ (g)}}{\text{(g-mole)}} \cdot \frac{\text{(g-mole)}}{24.5 \text{ (L)}} \cdot \frac{1000 \text{ (L)}}{\text{(m}^3\text{)}}$$

$$2. AI = \frac{Ce \text{ (g)}}{\text{(m}^3\text{)}} \cdot \frac{0.0283 \text{ (m}^3\text{)}}{\text{(ft}^3\text{)}} \cdot \frac{Q \text{ (ft}^3\text{)}}{\text{(min)}} \cdot \frac{1440 \text{ (min)}}{\text{(day)}} \cdot \frac{\text{(lb)}}{454 \text{ (g)}}$$



Notes/Assumptions:

1. Assumes 60 F and 1 atm.
2. Influent estimates derived from pilot test data.
3. $ppmv = ug/l\text{-vapor} \times .18265$

APPENDIX G

PNEUMATIC PERMEABILITY CALCULATIONS

SVE Treatability Study-Air Permeability

Data Reduction

(Data)

I.D.	Time,t (Min.)	ln (t)	Pressure (in. Water)	I.D.	Time,t (Min.)	ln (t)	Pressure (in. Water)
3B	5	1.6094	0.150	4B	10	2.3026	0.000
	10	2.3026	0.150		20	2.9957	0.100
	15	2.7081	0.160		30	3.4012	0.120
	20	2.9957	0.160		40	3.6889	0.120
	25	3.2189	0.170		50	3.9120	0.120
	30	3.4012	0.180		60	4.0943	0.120
5B	5	1.6094	0.350		70	4.2485	0.130
	10	2.3026	0.420		80	4.3820	0.130
	15	2.7081	0.420		90	4.4998	0.140
	20	2.9957	0.440	6B	10	2.3026	0.000
	25	3.2189	0.450		20	2.9957	0.010
	30	3.4012	0.470		30	3.4012	0.030
7B	5	1.6094	0.500		40	3.6889	0.030
	10	2.3026	1.000		50	3.9120	0.030
	15	2.7081	1.000		60	4.0943	0.040
	20	2.9957	1.000		70	4.2485	0.045
	25	3.2189	1.000		80	4.3820	0.050
	30	3.4012	1.000		90	4.4998	0.060
				8B	10	2.3026	0.100
					20	2.9957	0.150
					30	3.4012	0.190
					40	3.6889	0.190
					50	3.9120	0.190
					60	4.0943	0.200
					70	4.2485	0.200
					80	4.3820	0.200
					90	4.4998	0.210

SVE Treatability Study-Air Permeability

Data Reduction

(Data, cont'd)

I.D.	Time, t (Min.)	ln (t)	Pressure (in. Water)	I.D.	Time, t (Min.)	ln (t)	Pressure (in. Water)
3C	5	1.6094	0.39	4C	10	2.3026	0.100
	10	2.3026	0.42		20	2.9957	0.110
	15	2.7081	0.42		30	3.4012	0.110
	20	2.9957	0.42		40	3.6889	0.115
	25	3.2189	0.42		50	3.9120	0.120
	30	3.4012	0.42		60	4.0943	0.120
	35	3.5553	0.42		70	4.2485	0.130
	40	3.6889	0.42		80	4.3820	0.130
	45	3.8067	0.42		90	4.4998	0.130
5C	5	1.6094	0.45	6C	10	2.3026	0.250
	10	2.3026	0.48		20	2.9957	0.290
	15	2.7081	0.48		30	3.4012	0.290
	20	2.9957	0.48		40	3.6889	0.290
	25	3.2189	0.48		50	3.9120	0.290
	30	3.4012	0.48		60	4.0943	0.290
	35	3.5553	0.48		70	4.2485	0.290
	40	3.6889	0.48		80	4.3820	0.290
	45	3.8067	0.48		90	4.4998	0.290
7C	5	1.6094	0.90	8C	10	2.3026	0.050
	10	2.3026	1.00		20	2.9957	0.100
	15	2.7081	1.00		30	3.4012	0.180
	20	2.9957	1.00		40	3.6889	0.180
	25	3.2189	1.00		50	3.9120	0.200
	30	3.4012	1.00		60	4.0943	0.240
	35	3.5553	1.00		70	4.2485	0.250
	40	3.6889	1.00		80	4.3820	0.280
	45	3.8067	1.00		90	4.4998	0.280

SVE Treatability Study-Air Permeability

Data Reduction

(Data, cont'd)

I.D.	Time,t (Min.)	ln (t)	Pressure (in. Water)	I.D.	Time,t (Min.)	ln (t)	Pressure (in. Water)
3A	10	2.3026	0.020	4A	10	2.3026	0.000
	20	2.9957	0.020		20	2.9957	0.000
	30	3.4012	0.020		30	3.4012	0.000
	40	3.6889	0.020		40	3.6889	0.100
	50	3.9120	0.020		50	3.9120	0.150
	60	4.0943	0.020		60	4.0943	0.180
	70	4.2485	0.025		70	4.2485	0.200
	80	4.3820	0.025		80	4.3820	0.240
5A	10	2.3026	0.400	6A	90	4.4998	0.250
	20	2.9957	0.420		10	2.3026	0.000
	30	3.4012	0.420		20	2.9957	0.000
	40	3.6889	0.410		30	3.4012	0.080
	50	3.9120	0.410		40	3.6889	0.150
	60	4.0943	0.410		50	3.9120	0.200
	70	4.2485	0.420		60	4.0943	0.280
	80	4.3820	0.420		70	4.2485	0.320
7A	10	2.3026	0.280	8A	80	4.3820	0.390
	20	2.9957	0.280		90	4.4998	0.390
	30	3.4012	0.280		10	2.3026	0.000
	40	3.6889	0.120		20	2.9957	0.100
	50	3.9120	0.120		30	3.4012	0.120
	60	4.0943	0.120		40	3.6889	0.200
	70	4.2485	0.120		50	3.9120	0.240
	80	4.3820	0.120		60	4.0943	0.300
					70	4.2485	0.300
					80	4.3820	0.300
					90	4.4998	0.330

SVE Treatability Study-Air Permeability

Data Reduction

(Results, cont'd)

3A

Regression Output:

Constant	0.014052
Std Err of Y Est	0.001995
R Squared	0.363507
No. of Observations	8
Degrees of Freedom	6

A=slope=	0.0019839
B=intercept=	0.014052

Radial distance from extraction well=	1770	cm
Air filled soil void fraction	=	0.25

X Coefficient(s)	0.001984
Std Err of Coef.	0.001072

k =	7.383E-08	cm ²
	=	7.4806397 Darcys

5A

Regression Output:

Constant	0.39447
Std Err of Y Est	0.006949
R Squared	0.252377
No. of Observations	8
Degrees of Freedom	6

A=slope=	0.0053139
B=intercept=	0.3944704

Radial distance from extraction well=	410	cm
Air filled soil void fraction	=	0.25

X Coefficient(s)	0.005314
Std Err of Coef.	0.003734

k =	5.769E+20	cm ²
	=	5.845E+28 Darcys

7A

Regression Output:

Constant	0.546231
Std Err of Y Est	0.046028
R Squared	0.735177
No. of Observations	8
Degrees of Freedom	6

A=slope=	-0.100941
B=intercept=	0.5462309

Radial distance from extraction well=	1520	cm
Air filled soil void fraction	=	0.25

X Coefficient(s)	-0.10094
Std Err of Coef.	0.024733

k =	2.041E-13	cm ²
	=	2.068E-05 Darcys

SVE Treatability Study-Air Permeability

Data Reduction

(Results, cont'd)

4A

Regression Output:

Constant -0.36788
Std Err of Y Est 0.043633
R Squared 0.844352
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.1321669

B=intercept= -0.367879

Radial distance from extraction well= 460 cm

Air filled soil void fraction = 0.15

X Coefficient(s) 0.132167
Std Err of Coef. 0.021448

k = 1.553E-13 cm²

= 1.573E-05 Darcys

6A

Regression Output:

Constant -0.5508
Std Err of Y Est 0.055106
R Squared 0.888056
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.2018542

B=intercept= -0.550798

Radial distance from extraction well= 210 cm

Air filled soil void fraction = 0.15

X Coefficient(s) 0.201854
Std Err of Coef. 0.027087

k = 3.418E-14 cm²

= 3.463E-06 Darcys

8A

Regression Output:

Constant -0.37188
Std Err of Y Est 0.020735
R Squared 0.971063
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.1562098

B=intercept= -0.371883

Radial distance from extraction well= 710 cm

Air filled soil void fraction = 0.15

X Coefficient(s) 0.15621
Std Err of Coef. 0.010192

k = 5.533E-13 cm²

= 5.606E-05 Darcys

Carrier Collierville
SVE Treatability Study-Air Permeability
Data Reduction
(Results)

03-Jan-94

3B

Regression Output:

Constant 0.119721
Std Err of Y Est 0.006241
R Squared 0.772022
No. of Observations 6
Degrees of Freedom 4

A=slope= 0.0155012
B=intercept= 0.1197206

Radial distance from extraction well= 1585 cm
Air filled soil void fraction = 0.25

X Coefficient(s) 0.015501
Std Err of Coef. 0.004212

k = 1.123E-07 cm²
= 11.380071 Darcys

5B

Regression Output:

Constant 0.261443
Std Err of Y Est 0.011502
R Squared 0.938103
No. of Observations 6
Degrees of Freedom 4

A=slope= 0.0604426
B=intercept= 0.2614434

Radial distance from extraction well= 411 cm
Air filled soil void fraction = 0.25

X Coefficient(s) 0.060443
Std Err of Coef. 0.007763

k = 2.526E-10 cm²
= 0.0255927 Darcys

7B

Regression Output:

Constant 0.240911
Std Err of Y Est 0.133618
R Squared 0.657206
No. of Observations 6
Degrees of Freedom 4

A=slope= 0.2497269
B=intercept= 0.2409107

Radial distance from extraction well= 100 cm
Air filled soil void fraction = 0.25

X Coefficient(s) 0.249727
Std Err of Coef. 0.090178

k = 5.19E-13 cm²
= 5.259E-05 Darcys

SVE Treatability Study-Air Permeability

Data Reduction

(Results, cont'd)

4B

Regression Output:

Constant -0.08244
Std Err of Y Est 0.021942
R Squared 0.764139
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.0513633
B=intercept= -0.08244

Radial distance from extraction well= 457 cm
Air filled soil void fraction = 0.15

X Coefficient(s) 0.051363
Std Err of Coef. 0.010786

k = 4.979E-13 cm²
= 5.045E-05 Darcys

6B

Regression Output:

Constant -0.0619
Std Err of Y Est 0.005101
R Squared 0.936223
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.0254158
B=intercept= -0.061896

Radial distance from extraction well= 152 cm
Air filled soil void fraction = 0.15

X Coefficient(s) 0.025416
Std Err of Coef. 0.002507

k = 2.401E-14 cm²
= 2.433E-06 Darcys

8B

Regression Output:

Constant 0.011738
Std Err of Y Est 0.012718
R Squared 0.883133
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.0454693
B=intercept= 0.0117377

Radial distance from extraction well= 580 cm
Air filled soil void fraction = 0.15

X Coefficient(s) 0.045469
Std Err of Coef. 0.006252

k = 5.168E-12 cm²
= 0.0005236 Darcys

SVE Treatability Study-Air Permeability

Data Reduction

(Results, cont'd)

3C

Regression Output:

Constant 0.385406
Std Err of Y Est 0.007172
R Squared 0.54998
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.0103107
B=intercept= 0.3854062

Radial distance from extraction well= 1460 cm
Air filled soil void fraction = 0.25

X Coefficient(s) 0.010311
Std Err of Coef. 0.003525

k = 722078.82 cm²
= 7.316E+13 Darcys

5C

Regression Output:

Constant 0.445406
Std Err of Y Est 0.007172
R Squared 0.54998
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.0103107
B=intercept= 0.4454062

Radial distance from extraction well= 870 cm
Air filled soil void fraction = 0.25

X Coefficient(s) 0.010311
Std Err of Coef. 0.003525

k = 86332135 cm²
= 8.747E+15 Darcys

7C

Regression Output:

Constant 0.884687
Std Err of Y Est 0.023905
R Squared 0.54998
No. of Observations 9
Degrees of Freedom 7

A=slope= 0.0343689
B=intercept= 0.8846872

Radial distance from extraction well= 1020 cm
Air filled soil void fraction = 0.25

X Coefficient(s) 0.034369
Std Err of Coef. 0.011751

k = 3.1086303 cm²
= 314957482 Darcys

Carrier Collierville
SVE Treatability Study-Air Permeability
Data Reduction

03-Jan-94

(Results, cont'd)

4C

Regression Output:

Constant	0.065489
Std Err of Y Est	0.003096
R Squared	0.925471
No. of Observations	9
Degrees of Freedom	7

A=slope=	0.0141863
B=intercept=	0.065489

Radial distance from extraction well=	460	cm
Air filled soil void fraction	=	0.15

X Coefficient(s)	0.014186
Std Err of Coef.	0.001522

k =	2.539E-10	cm ²
	=	0.0257288 Darcys

6C

Regression Output:

Constant	0.234346
Std Err of Y Est	0.009562
R Squared	0.54998
No. of Observations	9
Degrees of Freedom	7

A=slope=	0.0137475
B=intercept=	0.2343458

Radial distance from extraction well=	150	cm
Air filled soil void fraction	=	0.15

X Coefficient(s)	0.013748
Std Err of Coef.	0.0047

k =	6.756E-06	cm ²
	=	684.50973 Darcys

8C

Regression Output:

Constant	-0.20855
Std Err of Y Est	0.013704
R Squared	0.973718
No. of Observations	9
Degrees of Freedom	7

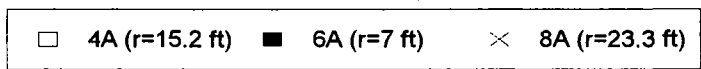
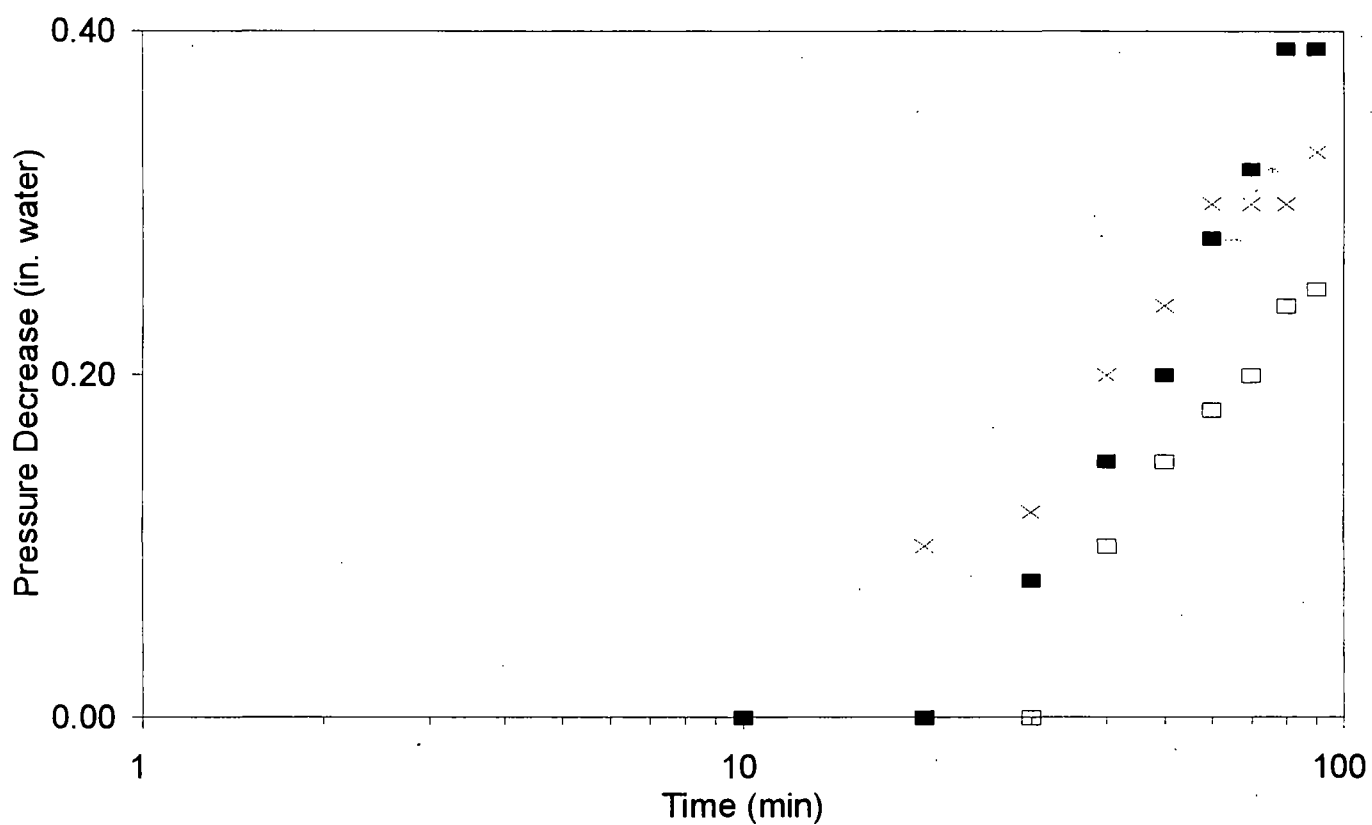
A=slope=	0.1084841
B=intercept=	-0.208549

Radial distance from extraction well=	610	cm
Air filled soil void fraction	=	0.15

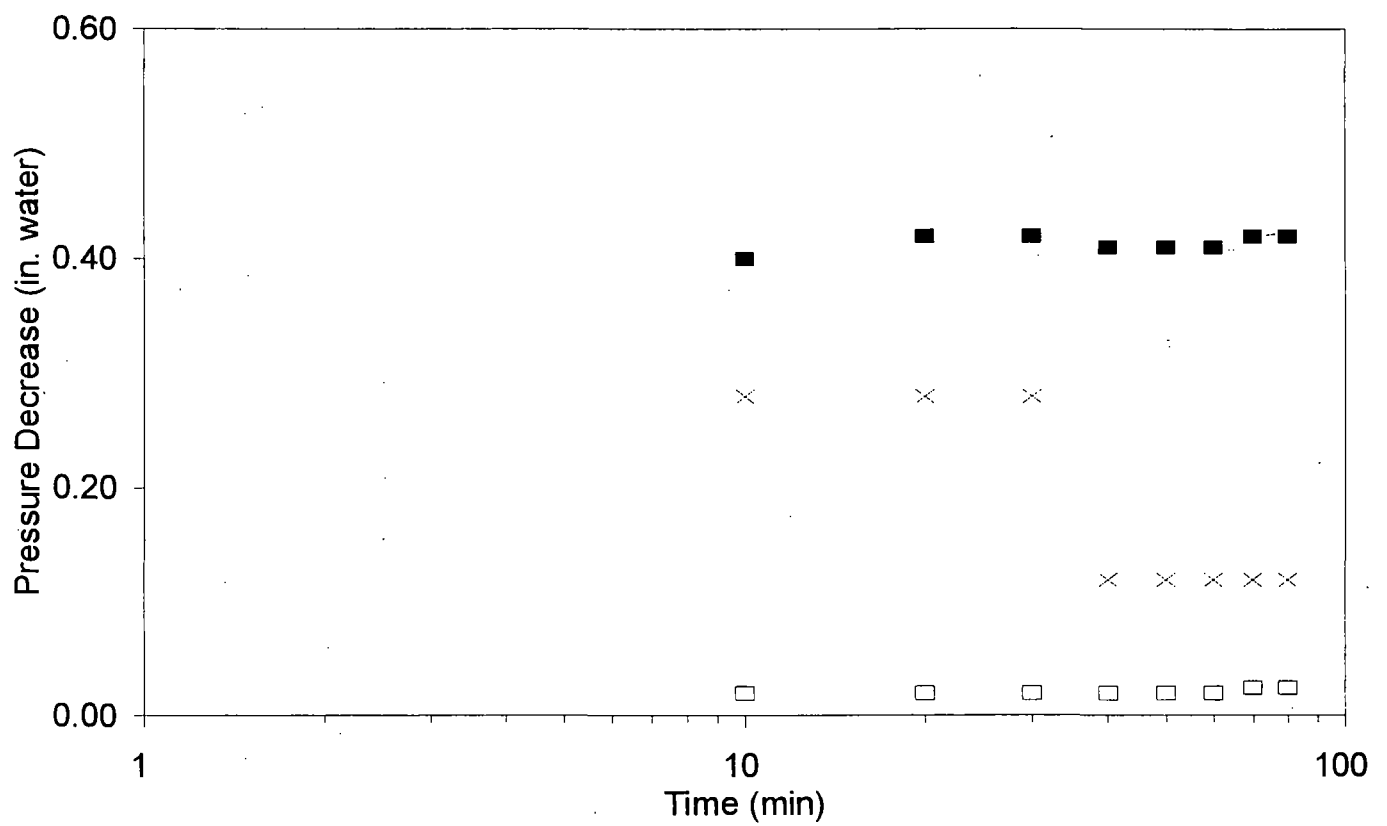
X Coefficient(s)	0.108484
Std Err of Coef.	0.006736

k =	6.459E-13	cm ²
	=	6.544E-05 Darcys

Area A
Shallow



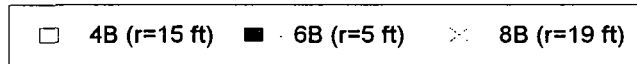
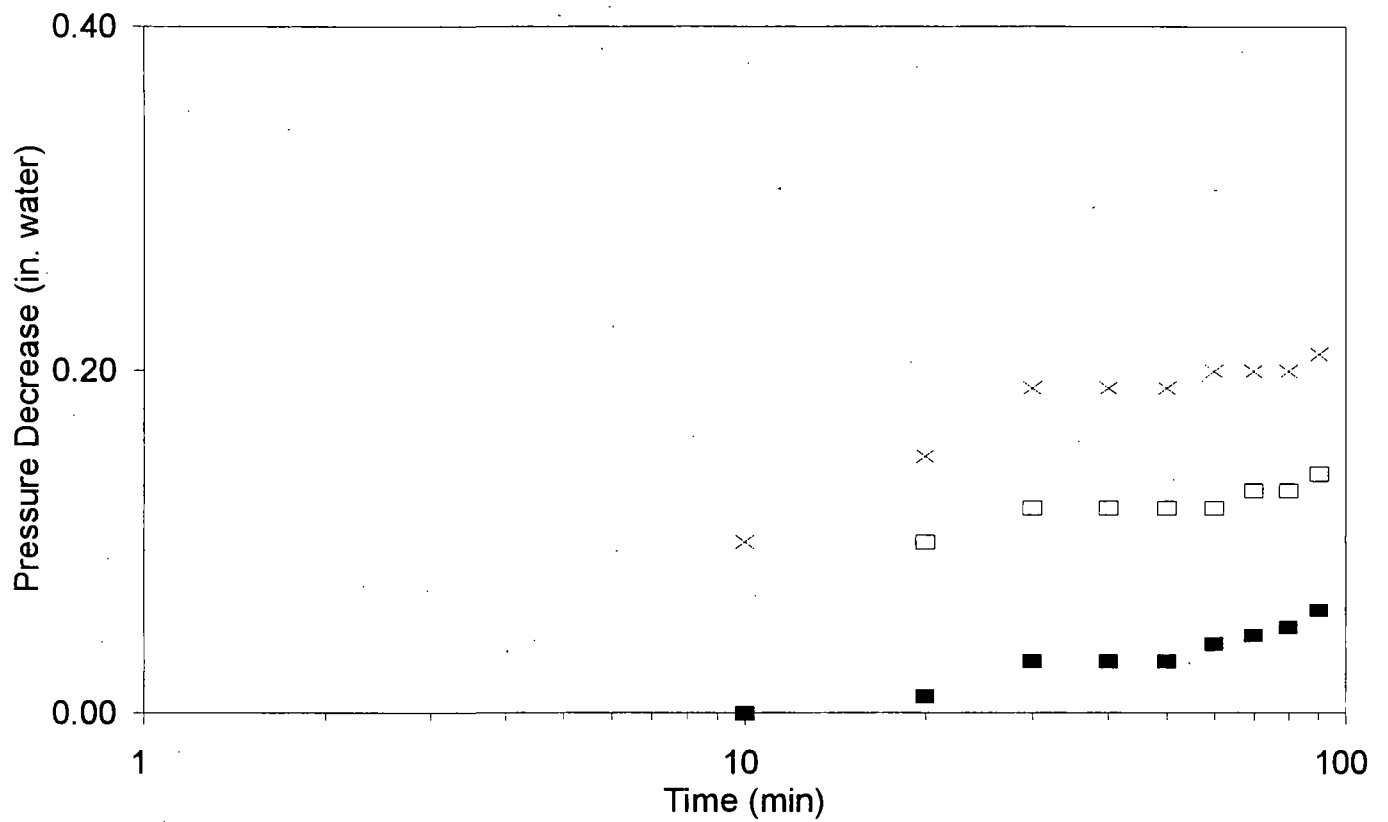
Area A
Deep



□ 3A (r=58.1 ft) ■ 5A (r=13.4 ft) × 7A (r=50 ft)

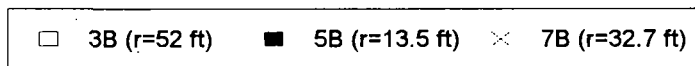
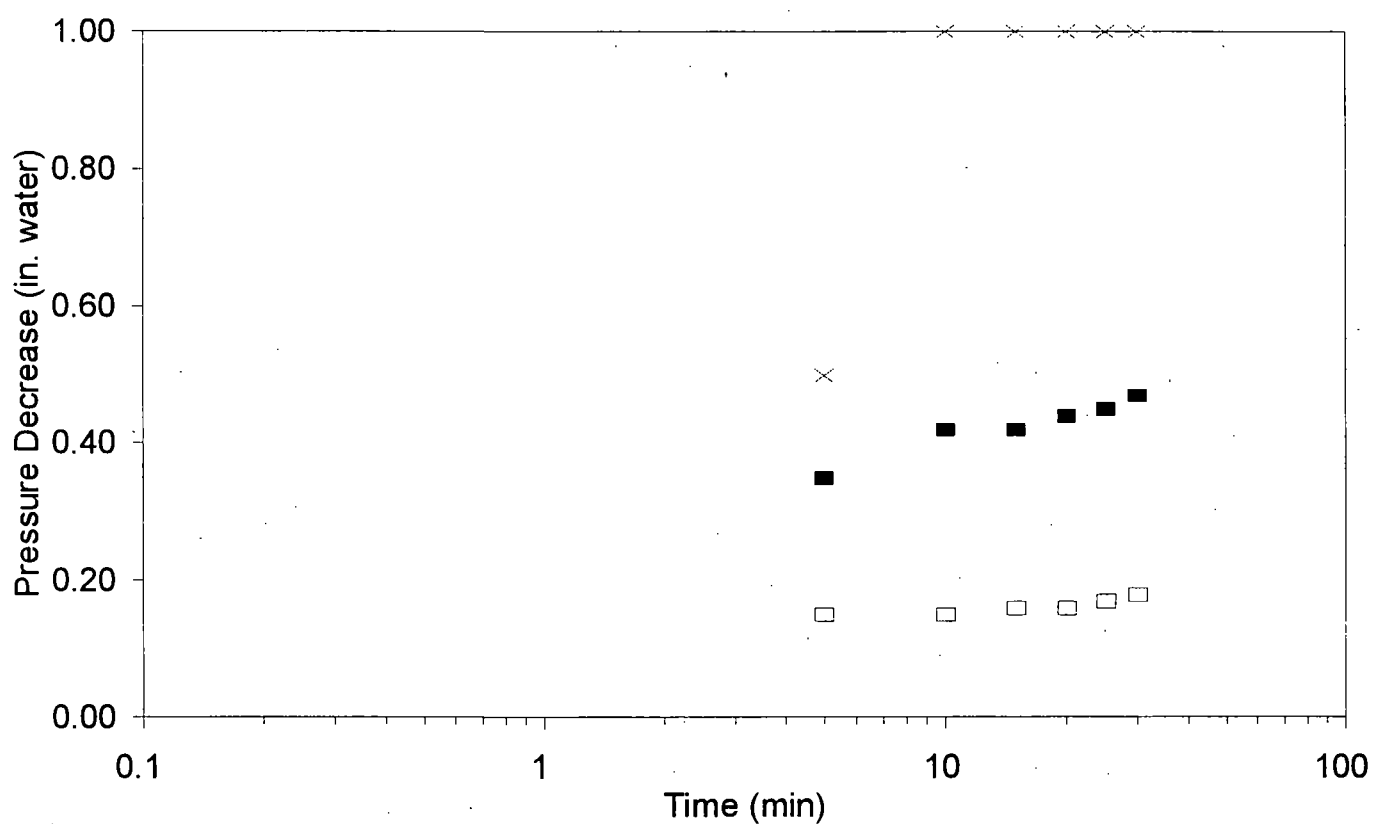
Area B

Shallow



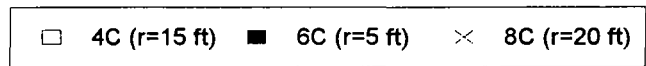
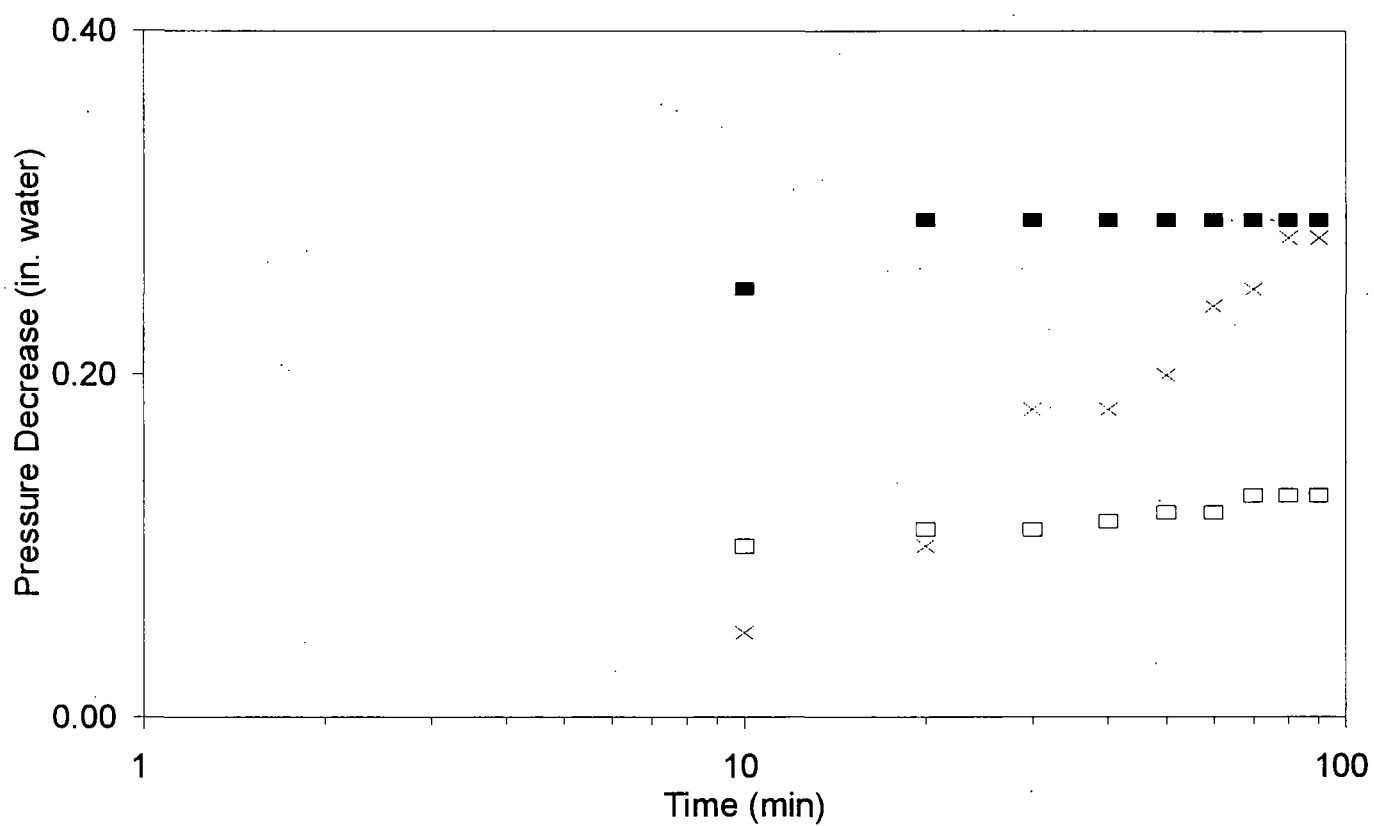
Area B

Deep

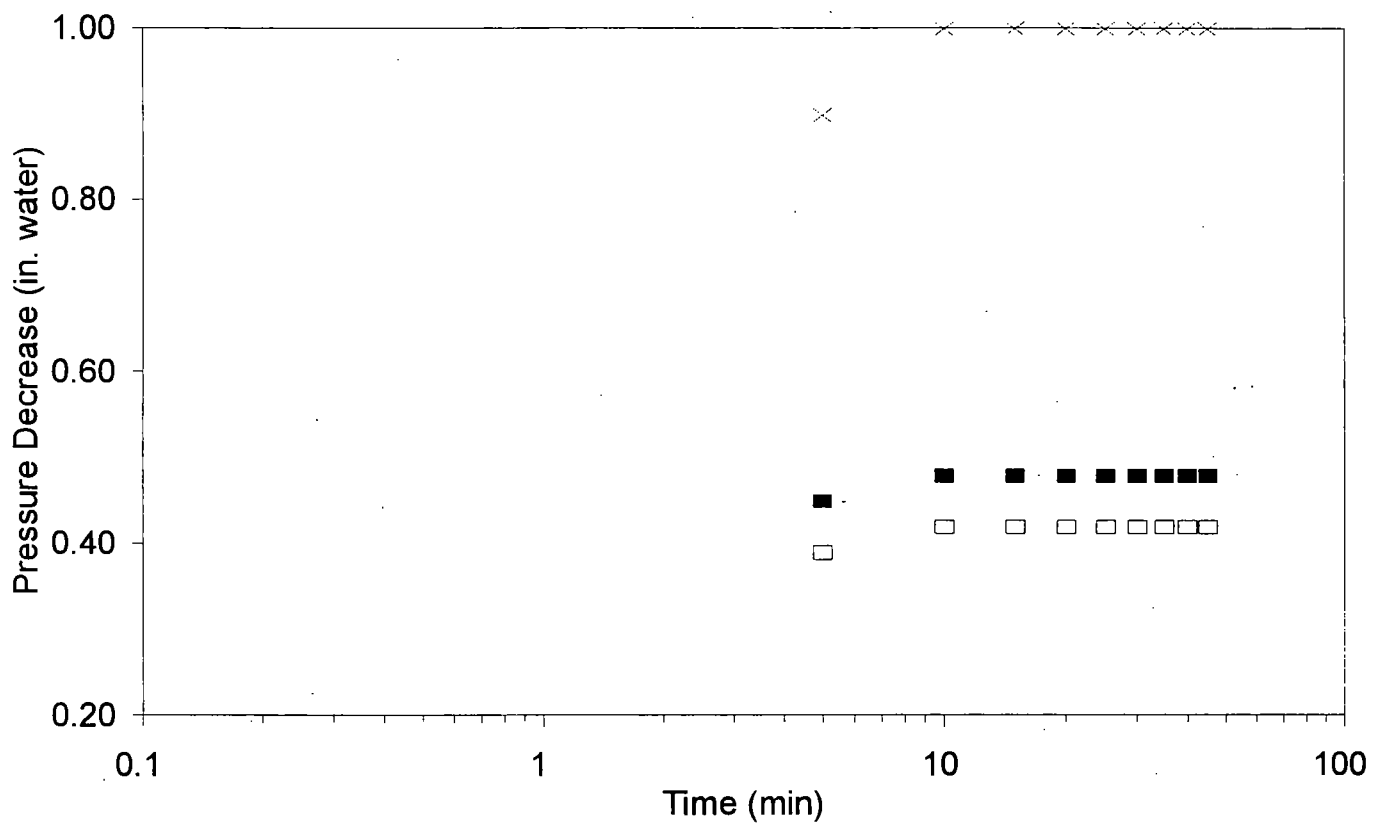


Area C

Shallow



Area C
Deep



□ 3C (r=48 ft) ■ 5C (r=28.5 ft) × 7C (r=33.5 ft)

APPENDIX H

EFFECTIVE RADIUS OF INFLUENCE CALCULATIONS

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

Site/Area:	Area A, Shallow
Elapsed Time:	30 (minutes)
Wellhead Vacuum:	47 (in. H ₂ O)
Effective Vac. Level:	0.047 (in. H ₂ O)

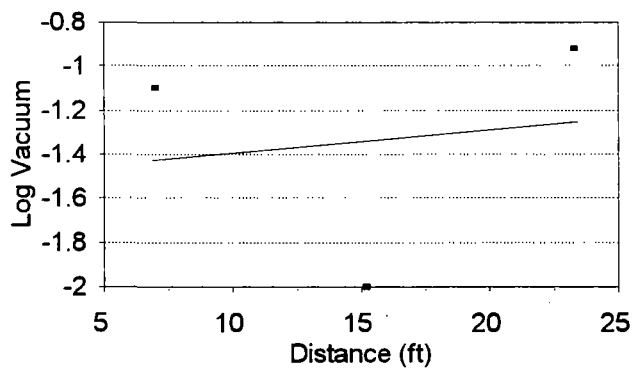
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
7.00	0.080	-1.10
15.20	0.010	-2.00
23.30	0.120	-0.92

Regression Output:

Constant	-1.49932
Std Err of Y Est	0.809695
R Squared	0.02207
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	0.01055
Std Err of Coef.	0.07025

Subsurface Vacuum vs. Distance



Results

Slope = 0.01055
Intercept = -1.49932
Correlation = 0.02207

Calculated Effective Radius of Influence

EROI = 16 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

Site/Area:	Area A, Shallow
Elapsed Time:	90 (minutes)
Wellhead Vacuum:	47 (in. H ₂ O)
Effective Vac. Level:	0.047 (in. H ₂ O)

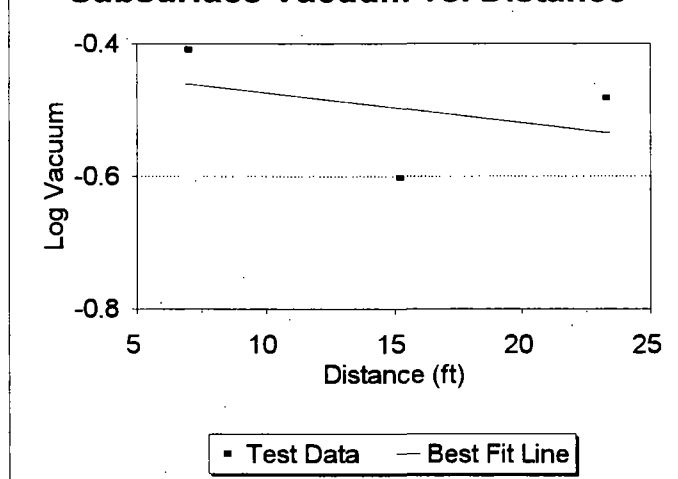
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
7.00	0.390	-0.41
15.20	0.250	-0.60
23.30	0.330	-0.48

Regression Output:

Constant	-0.42939
Std Err of Y Est	0.127884
R Squared	0.14073
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.00449
Std Err of Coef.	0.01110

Subsurface Vacuum vs. Distance



Results

Slope = -0.00449
Intercept = -0.42939
Correlation = 0.14073

Calculated Effective Radius of Influence

EROI = 200 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

Site/Area:	Area A, Deep
Elapsed Time:	20 (minutes)
Wellhead Vacuum:	47 (in. H ₂ O)
Effective Vac. Level:	0.047 (in. H ₂ O)

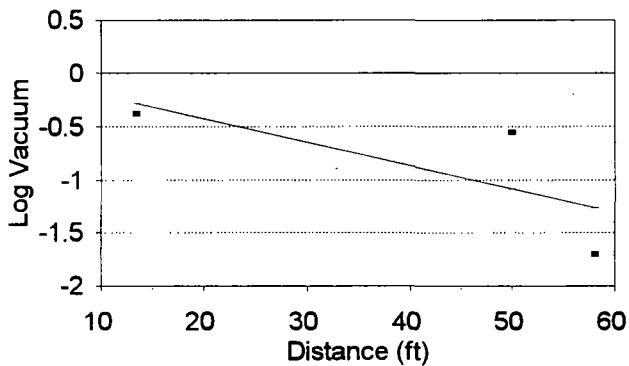
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
13.40	0.420	-0.38
50.00	0.280	-0.55
58.10	0.020	-1.70

Regression Output:

Constant	0.014337
Std Err of Y Est	0.694613
R Squared	0.53200
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.02199
Std Err of Coef.	0.02062

Subsurface Vacuum vs. Distance



Results

Slope =	-0.02199
Intercept =	0.01434
Correlation =	0.53200

Calculated Effective Radius of Influence

EROI = 61 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

Site/Area:	Area A, Deep
Elapsed Time:	45 (minutes)
Wellhead Vacuum:	47 (in. H ₂ O)
Effective Vac. Level:	0.047 (in. H ₂ O)

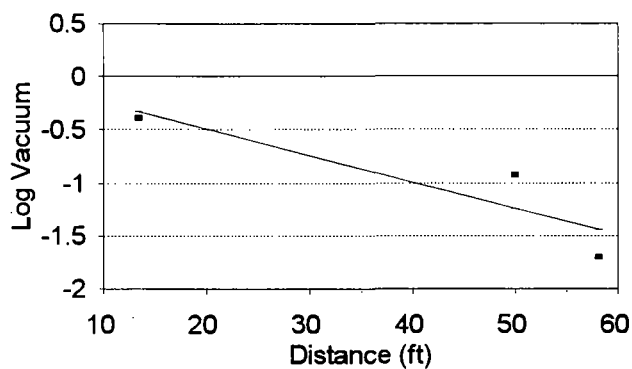
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
13.40	0.410	-0.39
50.00	0.120	-0.92
58.10	0.020	-1.70

Regression Output:

Constant	0.002867
Std Err of Y Est	0.41411
R Squared	0.80296
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.02482
Std Err of Coef.	0.01230

Subsurface Vacuum vs. Distance



Results

Slope = -0.02482
Intercept = 0.00287
Correlation = 0.80296

Calculated Effective Radius of Influence

EROI = 54 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

ROI Determination

Site Data Input:

Site/Area:	Area B, Shallow
Elapsed Time:	30 (minutes)
Wellhead Vacuum:	54 (in. H ₂ O)
Effective Vac. Level:	0.054 (in. H ₂ O)

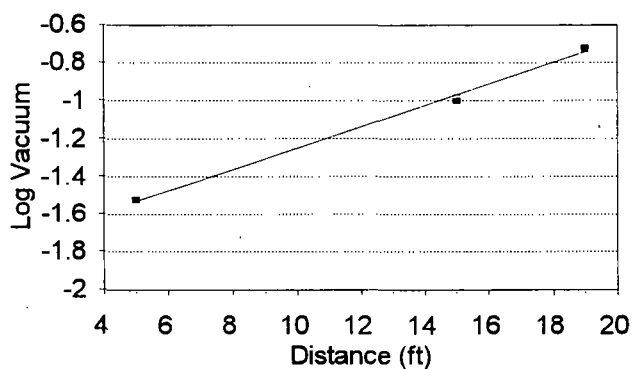
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
5.00	0.030	-1.52
15.00	0.100	-1.00
19.00	0.190	-0.72

Regression Output:

Constant	-1.81332
Std Err of Y Est	0.039404
R Squared	0.99531
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	0.05630
Std Err of Coef.	0.00386

Subsurface Vacuum vs. Distance



Results

Slope = 0.05630
Intercept = -1.81332
Correlation = 0.99531

Calculated Effective Radius of Influence

EROI = 10 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

ROI Determination

Site Data Input:

Site/Area:	Area B, Shallow
Elapsed Time:	90 (minutes)
Wellhead Vacuum:	54 (in. H ₂ O)
Effective Vac. Level:	0.054 (in. H ₂ O)

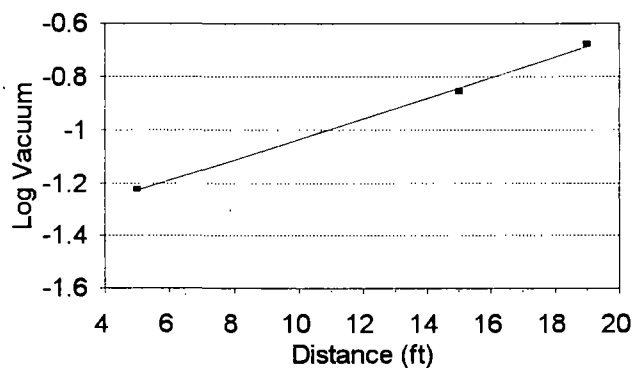
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
5.00	0.060	-1.22
15.00	0.140	-0.85
19.00	0.210	-0.68

Regression Output:

Constant	-1.41788
Std Err of Y Est	0.016362
R Squared	0.99826
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	0.03847
Std Err of Coef.	0.00160

Subsurface Vacuum vs. Distance



Results

Slope = 0.03847
Intercept = -1.41788
Correlation = 0.99826

Calculated Effective Radius of Influence

EROI = 4 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

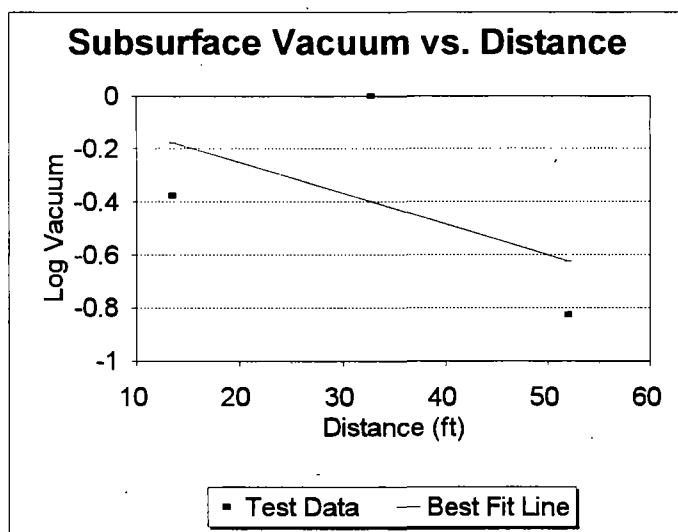
Site/Area:	Area B, Deep
Elapsed Time:	10 (minutes)
Wellhead Vacuum:	41 (in. H ₂ O)
Effective Vac. Level:	0.041 (in. H ₂ O)

Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
13.50	0.420	-0.38
32.70	1.000	0.00
52.00	0.150	-0.82

Regression Output:

Constant	-0.01916
Std Err of Y Est	0.489692
R Squared	0.29521
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.01164
Std Err of Coef.	0.01799



Results

Slope = -0.01164
Intercept = -0.01916
Correlation = 0.29521

Calculated Effective Radius of Influence

EROI = 118 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

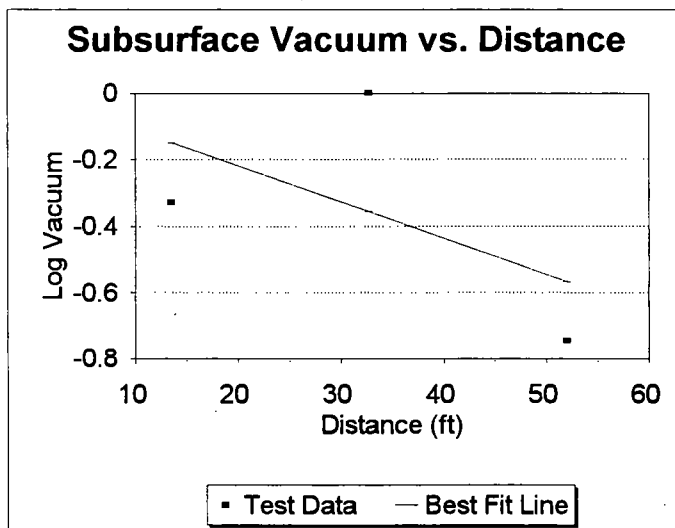
Site/Area:	Area B, Deep
Elapsed Time:	30 (minutes)
Wellhead Vacuum:	41 (in. H ₂ O)
Effective Vac. Level:	0.041 (in. H ₂ O)

Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
13.50	0.470	-0.33
32.70	1.000	0.00
52.00	0.180	-0.74

Regression Output:

Constant	-0.00236
Std Err of Y Est	0.437457
R Squared	0.31317
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.01085
Std Err of Coef.	0.01607



Results

Slope = -0.01085
Intercept = -0.00236
Correlation = 0.31317

Calculated Effective Radius of Influence

EROI = 128 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

Site/Area:	Area C, Shallow
Elapsed Time:	30 (minutes)
Wellhead Vacuum:	54 (in. H ₂ O)
Effective Vac. Level:	0.054 (in. H ₂ O)

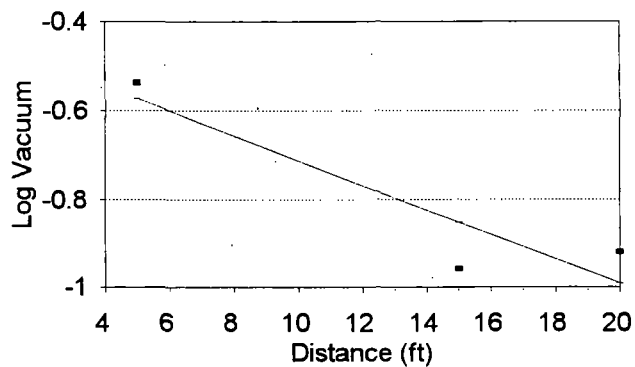
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
5.00	0.290	-0.54
15.00	0.110	-0.96
20.00	0.120	-0.92

Regression Output:

Constant	-0.43351
Std Err of Y Est	0.132717
R Squared	0.83767
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.02791
Std Err of Coef.	0.01229

Subsurface Vacuum vs. Distance



Results

Slope = -0.02791
Intercept = -0.43351
Correlation = 0.83767

Calculated Effective Radius of Influence

EROI = 30 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

Site/Area:	Area C, Shallow
Elapsed Time:	90 (minutes)
Wellhead Vacuum:	54 (in. H ₂ O)
Effective Vac. Level:	0.054 (in. H ₂ O)

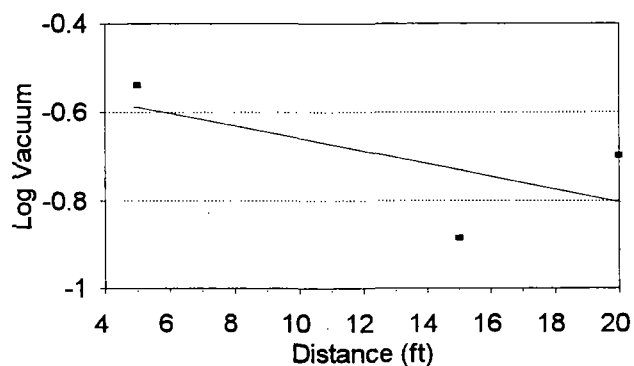
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
5.00	0.290	-0.54
15.00	0.130	-0.89
20.00	0.200	-0.70

Regression Output:

Constant	-0.51822
Std Err of Y Est.	0.19313
R Squared	0.38673
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.01420
Std Err of Coef.	0.01788

Subsurface Vacuum vs. Distance



Results

Slope = -0.01420
Intercept = -0.51822
Correlation = 0.38673

Calculated Effective Radius of Influence

EROI = 53 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

EROI Determination

Site Data Input:

Site/Area:	Area C, Deep
Elapsed Time:	10 (minutes)
Wellhead Vacuum:	41 (in. H ₂ O)
Effective Vac. Level:	0.041 (in. H ₂ O)

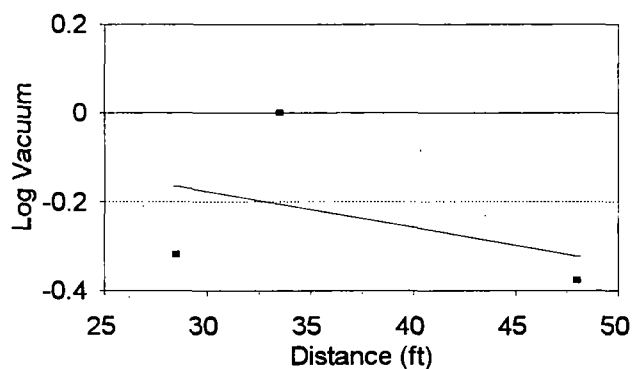
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
28.50	0.480	-0.32
33.50	1.000	0.00
48.00	0.420	-0.38

Regression Output:

Constant	0.06602
Std Err of Y Est	0.262231
R Squared	0.16450
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.00812
Std Err of Coef.	0.01831

Subsurface Vacuum vs. Distance



Results

Slope = -0.00812
Intercept = 0.06602
Correlation = 0.16450

Calculated Effective Radius of Influence

EROI = 179 (ft)

SOIL VENT PILOT TEST DATA REDUCTION

ROI Determination

Site Data Input:

Site/Area:	Area C, Deep
Elapsed Time:	45 (minutes)
Wellhead Vacuum:	41 (in. H ₂ O)
Effective Vac. Level:	0.041 (in. H ₂ O)

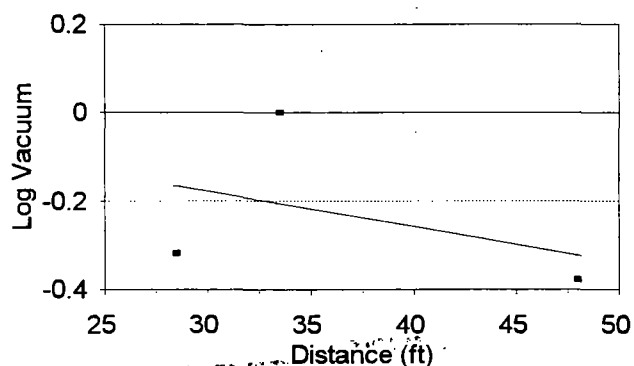
Measured Data Input:

Distance from SVE Pt. (ft)	Measured Vacuum (in. H ₂ O)	Log (base 10) Vacuum
28.50	0.480	-0.32
33.50	1.000	0.00
48.00	0.420	-0.38

Regression Output:

Constant	0.06602
Std Err of Y Est	0.262231
R Squared	0.16450
No. of Observations	3.00000
Degrees of Freedom	1
X Coefficient(s)	-0.00812
Std Err of Coef.	0.01831

Subsurface Vacuum vs. Distance



Results

Slope = -0.00812
Intercept = 0.06602
Correlation = 0.16450

Calculated Effective Radius of Influence

EROI = 179 (ft)